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Extract efficiency: 65%
(i.e. — 1 pound of 2-row malt, which has a potential extract value of 1.037 in one gallon of water, would yield a wort of 1.024.)

Extract values for malt extract:
liquid malt extract (LME) = 1.033–1.037
dried malt extract (DME) = 1.045

Potential extract for grains:
2-row base malts = 1.037–1.038
wheat malt = 1.037
6-row base malts = 1.035
Munich malt = 1.035
Vienna malt = 1.035
crystal malts = 1.033–1.035
chocolate malts = 1.034
dark roasted grains = 1.024–1.026
flaked maize and rice = 1.037–1.038

Hops:
We calculate IBUs based on 25% hop utilization for a one-hour boil of hop pellets at specific gravities less than 1.050. For post-boil hop stands, we calculate IBUs based on 10% hop utilization for 30-minute hop stands at specific gravities less than 1.050.

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Guide to All-Grain Brewing

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THE BASICS

While there is a sea of information about all-grain brewing, the core of what you need to know about brewing beer with malted grains is not complicated. The most important process to understand when stepping up to all-grain brewing is mashing, where malts are steeped in hot water to activate their enzymes and convert the starches into fermentable sugars. When this conversion is complete, the solution you are left with is the wort. If you have already brewed with extract, this step is done for you by the malt extract manufacturer. Malt extract is simply wort made from malted grains that have been mashed and the resulting liquid condensed into syrup or dried into a powder. If you're ready to make your own all-grain wort, get the basics under your belt and you'll be brewing in no time.

Photo by Charles A. Parker/Images Plus

Your First ALL-GRAIN BEER

Brew a homebrew with malted grains from start to finish

by **Chris Colby**

There are a couple of different ways to approach your first all-grain brew day. There is a vast amount of information in the homebrew literature, in print and on the Web, about all-grain brewing, and you could try to read most of it first and then proceed. Or, you could jump right in.

Firstly, although there is a lot of interesting technical information out there, you really only need to grasp a few key ideas to get started. As you continue to brew, you can keep learning and fill in any gaps in your education.

Secondly, learning to brew well at home requires some practical experience that you can only get by actually brewing . . . on your equipment, with your water, etc. Getting to know the mechanics of brewing — including the quirks of your setup — is just as important, in terms of beer quality, as knowing many of the more advanced academic ideas. Acquiring knowledge along both these paths at the same time will speed your journey from novice to experienced brewer.

In this article, we'll cover the bare minimum of technical information you need to get started and give a practical guide to successfully brewing your first all-grain beer. It is assumed that you are already familiar with brewing with malt extracts.

Required Knowledge (The Minimum)

All-grain brewing differs from extract brewing mainly in the wort production stage. As an extract brewer, you made your wort by dissolving malt extract in water, and likely steeping some specialty grains to add some additional flavors. As an all-grain brewer, you will make your wort from malted grains and water. The basic idea behind all-grain wort production is this:

You soak crushed, malted grains in hot water, then drain away the resulting liquid, which is your wort. That's it. There are, of course, subtleties that you will learn about later — how finely do you crush the malt, how hot should the grain and water mixture be, how fast do you drain the wort, etc. — but that's the basic idea.

If you have been boiling a dense wort of dissolved malt extract and then diluting it to working strength in your fermenter, you will now be boiling (and cooling) your full wort volume as well. Once your wort is in the fermenter, fermentation and conditioning is handled in the same way as in extract brewing.

Equipment

A typical all-grain homebrew set up includes three vessels. First, a vessel to heat all the water for your brewing session. As brewing water is sometimes called brewing liquor, the name of this vessel is the hot liquor tank, or HLT. Second, a

"All-grain brewing differs from extract brewing mainly in the wort production stage."

Photos by Charles A. Parker/Images Plus

Your first all-grain beer can be as simple as soaking crushed grains in hot water.

Photo by Chris Colby

A basic all-grain system includes three vessels: One to heat the strike water, called the hot liquor tank (HLT); one for holding the grains for mashing and lautering, called the mash (or lauter) tun; a third for boiling wort, which is the kettle. In the setup pictured, the HLT is on the bottom level, the mash tun is on the top level and the boiling kettle is on the middle level. A pump is used to move the liquids from one vessel to another.

Photo by Les Jorgensen

A false bottom, which is a type of screen or sieve, inside the mash tun allows the wort to flow out from the vessel while also keeping the grains inside.

vessel to hold the grains for both mashing (soaking the crushed grains) and lautering (separating the wort from the spent grains). This is called a mash/lauter tun (in commercial brewing, these are often separate vessels). This needs to have a false bottom or some sort of manifold installed to let the wort flow from the vessel while retaining the spent grains. You will also need a large paddle to stir the mash. Lastly, you need a vessel to boil the wort in, called the kettle.

A 5-gallon (19 L) homebrewery can consist of three 10-gallon/40-quart (38-L) vessels. Systems such as this work well for most average to moderately-big brews.

If you don't already have a wort chiller, you will need one. Quickly cooling your wort improves beer quality and a wort chiller works much faster and is more efficient than putting the kettle in a bath of cool water.

Finally, you will need a heat source capable of boiling your entire pre-boil volume of wort vigorously. For 5.0-gallon (19-L) batches, you will need to boil at least 6 gallons (23 L), more if you want to make high-gravity beers. For many all-grain homebrewers, the heat source of choice is a propane burner.

There are a lot of options when it comes to choosing all-grain equipment, too many to detail here. Keep in mind that great homebrew has been made on a wide variety of brewing setups.

Calibration and Calculations

Before your first brew day, you should make a dipstick (or calibrate your sight glasses, if your brewery has those) so that you can measure the volume of liquid in your HLT and kettle. Likewise, calibrate any thermometers that you will be using.

Before starting any brew day, there are two easy calculations you should make — the amount of strike water (water to mix with the crushed grains) and the amount of sparge water (water to rinse the grain bed) you will need. These are explained later.

The Crush

For your first all-grain brew, you will probably buy crushed malt or get the malt crushed at your homebrew shop. When it's time to brew, take a handful of malt and look at it. With a good crush, you should see almost no whole kernels. Most kernels should be broken into two to four pieces. (We will discuss milling more in depth starting on page 16 of this issue.)

If you've bought, or have access to, a grain mill, you will gain experience over time adjusting it to get the best crush for you. For your first crush, however, see if the mill has a "default" setting. This is usually 0.045 inches (0.11 cm). This should give you a good crush and you can start fiddling with adjusting the mill gap when you get more experience.

The goal of the crush is to break the malt kernels open so that the hot strike water can dissolve the starchy endosperm in the malt. You don't need perfectly crushed grain to a have a successful first brew day, so don't worry about this too much. Do, however, examine your crushed grains every time you brew. When the time comes to really start fine-tuning your brewing procedures, this will be valuable to you. Make a note in your brewing notebook about how the crush looked to you.

Water Heating and Mash In

Once your equipment is set up, you will need to start heating your strike water. The amount of water required varies between 0.95 and 2.4 quarts of water per pound of grain (2–5 L/kg), and a good consistency — or mash thickness — for most beers is 1.25 and 1.375 qts./lb. (2.6–2.9 L/kg). So, to figure out how much water you need, take the weight of your grains and multiply by some number between 1.25 and 1.375 (or 2.6 through 2.9, if you use the metric system). The lower numbers will give you a little thicker mash than the higher numbers, although the specified range is all in the "moderate" range of mash thickness.

If your mash vessel has a false bottom, add the volume under your false bottom to the amount of strike water you need to heat. For example, if there is a gallon (3.8 L) of space under your false bottom, add this extra one gallon

(3.8 L) of water to your strike water. All-grain brews require heating larger volumes of water than most extract brews, so be prepared for this step to take longer than you might think. If you have a metal mash paddle, set it in the HLT while the strike water is heating to warm it up.

Mixing the crushed grains and hot strike water is called "mashing in." The goal is to mix the crushed malt and water so that the grain bed settles in at your target temperature (which will be given in the homebrew recipe) and that this temperature is as uniform as possible throughout the grain bed.

The initial temperature after mash in depends mostly on the temperature of the strike water, the temperature of the crushed malt and the temperature of your mash vessel. There are equations that can help you calculate the temperature of your strike water, but most homebrewers "solve" this problem by using a generic recommendation and refining it with trial and error. One generic recommendation works fairly well if your grain and equipment are in the vicinity of "room temperature," and you use a mash thickness between 1.25 and 1.375 qts./lb. (2.6–2.9 L/kg). This is to heat your strike water to 11 °F (6 °C) above your target mash temperature. This method assumes no, or minimal, heat loss when transferring your strike water to your mash tun.

An improved recommendation — one that works better if your equipment is stored somewhere that is not temperature-controlled — is to adjust the temperature of your strike water once it is in your mash vessel. Heat your strike water to 15–18 °F (8–10 °C) over your target temperature and add the strike water to your mash vessel. Let it sit for two minutes and take the temperature. Now, adjust the temperature downward, towards 9–10 °F (5–5.5 °C) higher than your target temperature, by removing a couple cups of hot water and replacing it with the same volume of water around room temperature. Aim for 9 °F (5 °C) over if your mash thickness is 1.375 qts/lb. (2.9 L/kg), 10 °F (5.5 °C) over if your mash thickness is 1.25 qts./lb. (2.6 L/kg). Stir the water, take the temperature and repeat until you hit your target. This still assumes that your grain is near room temperature.

Once you've heated the measured amount of strike water and transferred it to the mash vessel, check again to see that it's in the right range (9–10 °F/5–5.5 °C above your target). Then, stir your crushed grains into the strike water. To do this, simply add a pound or so (~0.5 kg) of grain to the water, give a quick stir with your mash paddle until it immerses and repeat until all the grain is stirred in. Stir the grain for 20–30 seconds, looking to even out any temperature differences and break up any clumps of dry malt sticking together. Then, take the temperature and place the lid on your mash tun to conserve heat. Record the volume of the strike water, its temperature in your mash tun just prior to mashing in, and the initial mash temperature in your notes.

> "During the mash rest, your goal is to hold the grain bed at a constant, uniform temperature."

Resting

Now, you let the mash sit (or rest) for awhile. (The recipe should specify the length of this rest; often, it's one hour.) During the mash rest, your goal is to hold the grain bed at a constant, uniform temperature. Odds are, how-

Photo by Les Jorgensen

The cooler insulates the mash so that the brewer can maintain the target mash temperature throughout the grain bed.

Photo by Les Jorgensen

All-grain brewing often means brewing a full-size batch of at least 5-gallons (19 L) or more. A wort chiller such as this immersion chiller are necessary for cooling the full volume of wort down quickly.

Safety

As with anything, there are risks involved with all-grain brewing. However, if you are aware of what the dangers are and how to avoid them, you can brew safely for years without incident.

In commercial brewing, exposure to fumes from cleaning or sanitizing solutions can be a hazard. On the homebrew scale, this is rarely a concern, but — just to be safe — you should always mix or use any cleaning or sanitizing solutions in a well-ventilated area, and never mix products. With more and larger vessels, you will be making larger volumes of your usual solutions.

Burns and scalds are a risk in homebrewing, but a few rules of thumb will help you avoid these. Be aware that metal surfaces that are hot enough to burn you look just like cold surfaces. Before you transfer hot liquid (water or wort), from one vessel to another, make sure the valve on the receiving vessel is closed. Likewise, never start pumping hot liquids unless you know where the outflow is directed.

When you set up your brewing vessels, make sure they are not likely to tip over and are resting on a support capable of holding them when full. Try to route your tubing so that it is not likely that you, or anyone else, could get entangled and pull a vessel of hot liquid onto yourself. Likewise, be aware of tubing near ground level (such as the line from a propane tank) being a potential trip hazard.

In all-grain brewing, carrying vessels of hot liquid (for example, your kettle to a cold water bath for chilling) is not a good idea. Five gallons (19 L) of wort weighs over 40 lbs. (18 kg) and sloshing hot liquid can easily scald you. Try to set up your all-grain brewing equipment so that the vessels do not need to be moved during your brew day.

ever, you won't be able to do this. At a homebrew scale, the mash will lose heat over the time of the rest. And, the sides of the grain bed will cool off faster than the center. Fortunately, a small change in temperature is not going to hurt the quality of your beer. After your first mash, quickly take the temperature near the side of the mash vessel, and then near the center. Stir the mash to even out any temperature differences and take the temperature again. Record all three temperatures in your brewing notebook.

If your overall mash temperature drops more than 2 °F (1 °C), or the temperature difference within the mash is greater than 4 °F (2 °C), you should insulate your mash tun better next time. You can use towels or blankets for this. If your mash vessel is heatable, you can also add heat directly during the mash. If you do, stir the mash and do not heat too quickly.

During the rest, you have the option of stirring. Stirring ensures a more even mixture of grain and liquid and evens out temperature differences across the grain bed. Unfortunately, opening the mash vessel releases heat to the environment. Likewise, using a "cold" mash paddle absorbs more heat from the mash. As such, most homebrewers simply leave their mash undisturbed during this rest. If you overshot your mash temperature by a few degrees, stirring a couple times is an easy way to gradually bring the temperature down. Most homebrew recipes specify a one-hour rest for single infusion mashes.

Sparge Water

While the mash is resting, begin heating the water you will use to rinse the grain bed (the sparge water). How much sparge water will you need? I would recommend heating an amount equal to the target pre-boil volume of your wort, plus about 20%. This might seem like a huge amount, but this will allow you to collect your full pre-boil kettle volume, keep the grain bed in the mash/lauter vessel submerged throughout the wort collection process and have some extra water that serves as buffer against water in the "dead spaces" (tubing, etc.) loss to evaporation or small amounts of spillage. Running out of sparge water is a pain, whereas leftover hot water can be used for cleaning equipment. So, try to err on the side of heating too much sparge water. For a 5.0-gallon (19-L) batch, this may mean 7.5 gallons (28 L) or more. If you want to try to leave your grain bed dry at the end of sparging, subtract the volume of strike water from this amount. Also, if you mash out by adding boiling water to the grain bed (see the next section on mashing out), subtract this volume from the required volume of sparge water.

Your goal should be for the sparge water to be at the correct temperature when the mash is over and the wort has been recirculated. Use the length of time it took to heat the strike water to estimate how long it will take to heat the sparge water.

Mash Out

At the end of the mash, you have the option of performing a mash out. To mash out, you raise the temperature of the grain bed to 170 °F (77 °C). Mashing out makes the wort less viscous, and easier to collect. This can be done either by applying direct heat or by stirring in boiling water. If you heat the mash, be sure to stir as you do. If you add boiling water, you will need a volume that is approximately 40% of the volume of your strike water. Sometimes, the size of your mash tun will preclude you from adding enough water to reach 170 °F (77 °C). This is fine as you can simply rinse with hotter sparge water to compensate for this. Once you arrive at 170 °F (77 °C), or have added all the water your mash/lauter tun will hold, let the grain bed rest for five minutes and then you are ready to recirculate. Record the details of your mash out — final temperature and volume of boiling water added (if any).

Recirculation

The aim of recirculation is to draw some wort off from the bottom of the grain bed and return it to the top. Once enough wort has been recircu-

lated in this way, the wort clears up substantially. To recirculate manually, open the spigot to the mash/lauter tun slightly and slowly collect wort in a beer pitcher or similar vessel. Keep a timer running and collect wort at a rate that would fill the pitcher in about five minutes. Once full, gently pour the pitcher back on top of the grain bed. Repeat this until the wort looks clearer or 20 minutes have passed. Some homebrew rigs allow you to recirculate using a pump.

Wort Collection

Once recirculation is finished, it's time to start collecting wort. To do this, slowly open the valve on your mash/lauter tun and let the wort start trickling into the kettle. If your lauter tun is not positioned above the kettle, you can let the wort flow into a pitcher and then pour wort into the kettle. Collect the wort at a rate such that it takes about 60–90 minutes to collect the entire volume. To do this, keep the dip stick in the kettle and check on it every few minutes. Write down the time you start collecting wort and the time you cross the 1-gallon mark, 2-gallon mark, 3-gallon mark (or by similar liter increments if you are a metric brewer), etc.

You might think that simply leaving the ball valve on the spigot in the same position would keep the flow rate steady, but a lot changes as you are collecting wort. It gets progressively thinner, it may change in temperature and the amount of pressure from the water above the grain bed changes with the level. The grain bed itself can get compressed, slowing the flow of wort, So, especially on your first few brews, take a look every couple minutes at the amount of wort in the kettle and adjust the valve, if needed, to keep the wort flowing at the proper rate. Be especially careful to check your kettle after opening the valve to increase the flow of wort; if it starts to flow too quickly, you can drain the mash tun in a matter of minutes. Don't worry if wort collection doesn't go as planned on your first brew day. If you collect the wort too quickly, the only harm would likely be an original gravity slightly lower than you would have achieved otherwise.

When you first start collecting wort, there is a layer of water above the grain bed. Once the liquid level falls to almost the top of the grain bed, you should start applying sparge water. Your goal when sparging is to rinse "the good stuff" out of the grain bed, while not rinsing so extensively that you start extracting anything "bad."

The basic idea with continuous sparging is to apply water to the top of the grain bed at the same rate as it drains from the lauter tun. In theory, that should be simple. In practice it can be hard to match the flow rates. A simple way around this problem is to focus on getting the flow rate from the mash/tun to the kettle correct, then apply sparge water at a faster rate in intermittent bursts. Adding your sparge water in "pulses," rather than trying to get the flow rate to match the outflow from your mash/lauter tun is simple and lets you dictate how fast your kettle is filling.

You should heat your sparge water to the point that, as you sparge, the temperature of the grain bed approaches 170 °F (77 °C). If you mashed out to 170 °F (77 °C), and your lauter tun was well insulated, your sparge water should be 170 °F (77 °C) at the point that it is added. In this case, it may have to be hotter than 170 °F (77 °C) in the HLT if it travels through tubing (where it will lose temperature) on the way to your lauter tun. If your grain bed is cooler than this, then sparging with water at 190 °F (88 °C) or higher is appropriate until the grain bed reaches 170 °F (77 °C). Write down the details of your sparging in your brewing notebook.

When to Stop

There are a few ways to determine when to stop collecting your wort. For average-strength beers, the easiest way is just to quit collecting when you've got the full pre-boil wort volume in your kettle. With a propane burner, on homebrew-sized batches you can expect to boil off about a gallon an hour with a full rolling boil. So, for a 5-gallon (19 L) batch, you could collect 6 gallons (23 L) for a one-hour boil or 6.5 gallons (25 L) for a 90-minute boil.

A better way to know when to stop collecting wort is to monitor when you've gotten everything you reasonably can from the grain bed. The easiest way to do this is to take the specific gravity of your late runnings (the stream of wort you are collecting from the grain bed) and wait until it falls to about 1.008–1.010. If you do this, you may end up with more or less wort than your planned pre-boil wort volume. If you are low, as happens on many low-gravity brews, just add water. If you have collected more wort than you planned, you can extend the length of your boil.

When you are done collecting wort, write down the volume of wort in your kettle in your notes, the time you quit collecting and the original gravity of the wort. Also record if you needed to add any water to reach your target pre-boil volume.

Boiling and Beyond

For extract brewers who do full wort boils, the rest of your brew day is identical to what you are used to. If not, just expect that heating and cooling a larger volume of wort will take longer.

Now you know the basics of a first all-grain brew day. Most importantly, remember to record of all the relevant volumes, temperatures and times of your first all-grain batch in your notes. Before you grab a celebratory beer, write down any other observations that you feel may help you with future brews. Later, before your second brew, review your notes and determine what aspects of your brew day you want to improve upon. Knowledge comes quickly at first, so be sure to write absolutely everything down for your first several beers. BYO

Related Links:

• Looking to try all-grain brewing, but worrying about the cost of buying new equipment? Learn how to build an inexpensive mash/lauter vessel out of a cooler:
http://byo.com/story374

Base MALTS

The foundation grains that beers are built upon

by **Terry Foster**

Like any structure beer must have a foundation, which is what we call "base malt." When brewing with malt extract the choice of base malt has been made for you, but in the case of a partial mash/extract beer, or one from all-grain you have to choose it yourself. But before we get ahead of ourselves, what is base malt and what does it do in a beer?

Well, one of the most defining characteristics of beer is that it contains alcohol, which has been produced by the action of yeast on sugars. Not just any sugars, for there are some that yeast cannot ferment, but primarily simple sugars such as glucose, maltose, sucrose and to a lesser extent, maltotriose. These are produced in beer wort by enzymes that convert the starch in base malt to sugars during mashing. And of course the malt itself is derived from barley; there are other malts, notably wheat malt, which can perform this conversion, but they are generally used as base malts in a limited range of special beers, (and these will not be covered in this story.)

Base malts are the brewer's workhorse, and form the largest proportion of the malt bill, usually at least 60–80% of the total. They are the beer's source of alcohol, flavor foundation, some of its mouthfeel and body, and permit us to use whatever specialty malts and non-barley based grain starches we want to add. There are really only six of these, and they are as follows: pale malt, pale ale malt, Pilsner malt, mild ale malt, Vienna malt and Munich malt.

The first four can be used as the sole malt in the grain bill, and are true base malts. Vienna malt can also be used in this way although it is more often used in conjunction with pale malt. Munich malt (the very low roasted, low color versions – see later) can also be used as the sole source of fermentable sugars, but again is usually used alongside pale malt. In that sense these two are not really base malts, but I have included them because they are used in greater proportions of the malt bill than specialty malts.

Pale and Pale Ale Malt

These are the most important base malts and are used as such for the majority of beers brewed by craft and homebrewers. There are two basic types, 2-row and 6-row, which refers to the type of barley from which they are made. Six-row pale malt is very high in enzyme content and can hence handle quite high proportions of non-malt starchy grain adjuncts. Large commercial brewers mostly use them in this way since they are also high in protein, which can cause chill hazes in the final beer, unless low-protein adjuncts are added to lower the total protein content of the wort. Craft and homebrewers generally produce all-malt beers to get the kind

Pale malt is the most common base malt. It's used as the sole base malt in many commercial beers and homebrews.

Pale ale malt is like two-row, but is kilned at a higher temperature. This flavorful malt is used to make ales, especially traditional English ales.

Pilsner malt is used to brew traditional Czech or German Pilsners.

Photos by Ian Mackenzie

of flavors they want, and prefer to use 2-row types partly to reduce the risk of chill haze formation, and also because they help to give superior flavors.

At one time there was a big distinction between pale ale malt and 2-row and 6-row pale malt (as well as European lager malts), pale ale malt being held to be "well-modified," more so than the other base pale malts. What this meant was that the malting and kilning process for pale ale malt had been taken a little further along so that all that was needed to maximize extract from the malt was a single-temperature infusion mash. In contrast, US and European 2-row malts needed to go through a programmed schedule of gradually increasing temperatures to control both wort protein levels and to optimize extraction. Indeed, the process of decoction mashing, where the temperature increases are made by withdrawing a portion of the mash, boiling it and returning it to the main mash may well have arisen as a way to handle poorly-modified malts. That was then; modern pale malts are of much higher quality, and pretty much all well-modified enough to be converted by a single temperature infusion mash. But, programmed upward infusion is used by a number of brewers for brewing certain beers to reduce wort protein and to yield wort with somewhat different fermentability and therefore beer flavor profile. Some lager brewers still prefer to carry out a time-consuming decoction mash as they feel it produces a richer flavor, especially in something like a bock beer (read more about decoction mashing on page 73 of this issue). But in most cases you will get as good a result as you want by using a simple single temperature infusion, and I would recommend using this approach to all homebrewers unless your homebrew recipe specifically calls for a different mashing method.

So if they are both well-modified what then is the difference between pale malt and pale ale malt? Well, there may be slight flavor differences (read on), and even in maximum yields obtainable, but the latter are insignificant in practice. The main practical difference is principally that of color, with US 6-row and 2-row pale malts coming

> "Base malts are the brewer's workhorse, and form the largest proportion of the malt bill, usually at least 60–80% of the total."

Vienna malt has a malty flavor profile. It's used most often in Vienna lagers, but can also be used in other styles, such as IPA.

Munich malt is used in Oktoberfests and many German lagers, like dunkel. It also shows up in ales, from IPA to porter.

in at around 1.7–2.0 degrees Lovibond (°L), and UK pale malt at 2.5–3.5 °L. There is one other difference and that is in enzyme content, with US 6-row pale malt being the highest, US 2-row somewhat lower, and UK pale ale malt lower still. That is why 6-row pale can handle high levels of starchy adjuncts, but unless you plan to brew a high adjunct beer, we do not need to worry about the lower enzyme levels in 2-row and pale ale malt. With an all-malt beer these grains contain sufficient enzymes to achieve complete conversion in the mash, and to convert any residual starch, which may be present in specialty malts.

Exactly how much of these base malts you use in a particular beer depends upon a number of things, such as the alcoholic strength and what specialty malts may be needed for a particular style. Here I can deal only with strength, which is directly related to the yield you can get from the malt. So, what sort of yield can you expect from pale and pale ale malts? At a maximum (which means under ideal conditions) you will get an original gravity of 1.038–1.040 (9.5–10.0 °P) for the extract derived from 1 lb. (0.45 kg) of malt in one US gallon (3.8 L) of water. As you probably know, you will not get that sort of yield in practice, and *BYO* bases recipes on a brew house efficiency of 65%. That means that you can expect to get yields of 1.025–1.026 (6.3–6.6 °P) from one lb. in one gallon.

Here is an example: Let's say you want to brew 5 gallons (19 L) of a beer with an original gravity of 1.050 (12.5 °P), which for simplicity will be brewed with only pale malt. Then you will need total gravity points of 5 x 50 = 250. But pale ale malt gives 1.026 SG/lb./gallon, so we shall need 250/26 = 9.6 lb. (4.4 kg) of this malt.

Floor Malting

There is another type of pale ale malt, which is malt that has been floor malted. Most malts are produced via a drum malting process, during which the raw barley is first steeped in water until it has absorbed the appropriate amount of moisture, and then allowed to germinate. The drum is rotated and the temperature and moisture level of its contents are carefully controlled to ensure uniform germination of the barley. Once germination has proceeded sufficiently far, the green malt is then kilned to dry it. In the case of pale and pale ale malts this is done over a lengthy period, with the temperature rising slowly up to a maximum of about 170–180 °F (77–82 °C), depending upon exactly what the maltster intends to achieve. Generally pale ale malt is kilned at a slightly higher temperature than pale malt, hence its higher color. The great advantage of drum malting systems is that it permits the maltster to control the whole process to produce a high quality, uniform product.

Floor malting is a much older,

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more traditional, process than drum malting, although at first sight it seems the same in that it involves the identical stages of steeping, germination and kilning. The big difference is that in the germination stage the steeped barley is spread in a thin layer ("couch") on a floor. The germination has then to be controlled manually, in order to ensure uniform progress during growth. The big problem is temperature control, for considerable heat is generated by the germinating grain. This is done in two ways the first being by controlling atmospheric temperature by opening or closing louvered windows in the walls. The second way is by regular "turning" of the grain to ensure that hot spots do not develop in the bed. This is a totally manual process, carried out by men and/or women walking on the bed and turning it using wooden rakes and spades.

The main barley variety used in floor malting in Britain is Maris Otter, and with this the result is a plump rounded malt, perhaps a little darker in color than other pale ale malts at 3–4 °L. Opinions vary on its quality, but many brewers think that it adds a fuller, more rounded and even nuttier flavor to pale and bitter ales and IPAs than other pale ale malts.

Beyond the Pale

Now, I have largely talked about pale and pale ale malts in the context of pale beers, but they are also the base for nearly all kinds of beer, from pale lager to dark imperial stouts, and the question is whether it is always necessary to distinguish between them, or can they be considered as being interchangeable? It is partly a question of taste and some brewers would never use 2-row pale in a pale ale, or pale ale malt in a light lager. Others see 2-row malt as true workhorse and use it in every beer. Personally, I do not see the differences as being important in a beer brewed with a significant proportion of specialty malts. In other words, if the main flavor notes in the beer are caramel, biscuit, roasted and so on, these are going to dominate anything the base malts can supply, except for perhaps some body, which really comes from the mashing temperatures used. Therefore, in such beers you can use whatever base pale malt you prefer or happen to have on hand.

> "Some brewers would never use 2-row pale in a pale ale, or pale ale malt in a light lager."

Pilsner Malt

This is a version of pale malt, but is lighter in color (1–2 °L) than those discussed earlier, and is slightly less modified than they are. Do not be fooled by that statement, for it is modified well enough to be used by a single-temperature infusion mash. And it will give about the same extract yield, 1.025–1.026 per lb. per gallon at our 65% brewhouse efficiency. It gives a lighter, crisper flavored beer than other pales, and as its name suggests is ideally suited to brewing Pilsner beers, in which it is the only malt used. There is generally no advantage to using this malt in any kind of fuller-flavored or darker beer since in those styles the characteristics the malt is designed to produce would be lost.

Mild Ale Malt

Mild ale malt is produced just as pale ale malts, but is kilned at a slightly higher temperature, and is therefore a little more colored at around 3.5–4.5 °L, but still has a sufficiency of enzymes for most malt bills. As with the others it will yield around 1.025–1.026 per lb. per gallon at 65%, and can be mashed by the single-temperature approach. It gives a roasty, slightly sweeter and fuller flavor than pale ale malt, and can be used to advantage in mild ales as you might expect. Mild ales, which start at a low gravity, can be very light, bland and even boring, but if this malt is used as the base they can be almost luscious and even nutty on the palate. Further, mild ales are often brewed with a proportion of roasted malt, whose harshness can easily make the beer unbalanced, and mild ale will nicely balance that. But there is no reason, apart from that of color, to limit use of this malt to mild ales for it works well as a base in many beers, especially in dark ones.

Vienna Malt

This is another malt kilned slightly more than the pale ale malts, which may be made from either European 2-row and US 6-row barleys. It is relatively high in color (3–5 °L), and gives a slightly lower yield than pale malts, namely 1.023–1.024 per lb. per gallon for our 65% efficiency. Like our other base malts it has a significant enzyme content and can be fully converted in a simple infusion mash, but it often does not have enough enzymes to handle starches from adjuncts or specialty malts. It was originally designed for brewing Vienna lagers, however, it can be used in other beers, such as IPA.

Munich Malt

This is the highest kilned malt in this range and it may be as high as 30 °L in color. However, I am talking about lower kilned versions, which come in at 8–11 °L. Munich malt does contain enzymes and can be infusion mashed, giving a yield similar to that of Vienna malt, of 1.023 per lb. per gallon. However, Munich is rarely used on its own, and I would recommend always using it in combination with a pale malt, so it is only a quasi-base malt. But it does add a toasty flavor in a beer, as well as providing some good mouthfeel. I use this malt in a lot of beers, especially in pale and bitter ales where I want a little more body and flavor than I can get by simply using the more "normal" pale ale malt/crystal malt combination.

Extract to ALL-GRAIN

Adapt your favorite extract recipes to brew with grains, or convert your all-grain recipes over to extract

by **Terry Foster**

If you're ready to try all-grain brewing, what better way to start than with your own favorite extract recipes? With a little math you can make your extract recipe work for your all-grain system. With a little number manipulation and some understanding of the nature of various malts these conversions are straightforward.

A Simple Start

The first problem with converting homebrew recipes is that of "extract equivalency." In other words, how do you ensure that a converted recipe will match the original gravity of the starting recipe. Start by looking at *BYO*'s recipe standardization insert (see page 2), and use the numbers given there. Let's take a simple example first, say an all-grain 5-gallon (19 L) brew using 9.5 pounds (4 kg) of 2-row pale malt. *BYO* gives this as yielding an original gravity (OG) of 1.024 (or 24 "gravity points") when 1 pound is extracted into 1 gallon of water. So how much pale malt extract do we need to replace this grain? *BYO* says 1 pound of liquid malt extract (LME) in 1 gallon of water will give a gravity of 1.033–1.037; you probably won't know the exact figure, so let's assume it is 1.035 (or 35 gravity points) to minimize error, and then, doing the gravity point calculation:

$$9.5 \times 24 = W \times 35 \ldots (i)$$

Where W is the weight of LME in pounds, then W= (9.5 x 24) ÷ 35 = 6.5 lbs. of LME.

Photo by Michael Pollio

But often it is more convenient to take the whole number weight of LME, and make the rest up with dried malt extract (DME). *BYO* tells us that 1 pound of DME in 1 gallon of water gives a gravity of 1.045, so if in the above we assume we have only 6 pounds of LME, equation (i) is now written as follows:

$$9.5 \times 24 = (6 \times 35) + (WD \times 45) \ldots (ii)$$

Where WD is the weight of DME required.

Then $((9.5 \times 24) - (6 \times 35)) \div 45 =$ 0.4 lb = 6.4 oz. DME

If you had a recipe requiring 6 pounds of pale liquid malt extract, and 6 ounces (0.375 lb.) DME, the equivalent amount of 2-row pale malt (WM) would be given by:

$$WM = ((6 \times 35) + (0.375 \times 45)) \div 24 = 9.45 \text{ lbs. pale malt.}$$

The real world (I)

That example was a simple recipe, and often we want to convert more complicated recipes. So I am going to take such a recipe and go through the approach, starting with all-grain to extract. The first point to consider is what you can and can't do with specialty malts and adjuncts (other than base malts). In other words, you need to decide whether you can get what you want by a simple steeping procedure, or whether a partial-mash will be required.

Anything containing starch will require mashing, usually along with a proportion of pale malt to ensure the presence of sufficient enzymes to convert the starch into fermentables. These include amber, brown, special roast, Victory® and peat-smoked malts, as well as Munich, Vienna and rye malts (the last three can be mashed directly without added pale malt). Flaked cereals such as barley, oats, rice and so on also need to be utilized in a partial-mash, but I'll leave them out of this discussion since they are used for fairly specific purposes, and I don't want to complicate things too much.

More highly-roasted malts and

grains that do not contain starch (or enzymes) can be treated by steeping in hot water to obtain both flavor and extract. Consider the malt bill for this all-grain recipe for a dry stout:

Portly Stout
(5 gallons/19 L, all-grain)
OG = 1.063 FG = 1.015
ABV = 6.3% IBU = 50 SRM = 100

Ingredients
11.5 lbs. (5.2 kg) 2-row pale malt (2 °L)
0.5 lb. (0.23 kg) crystal malt (60 °L)
0.5 lb. (0.23 kg) chocolate malt (400 °L)
0.5 lb. (0.23 kg) brown malt (65 °L)
0.25 lb. (0.11 kg) black malt (550 °L)

The first thing to notice here is that we have four specialty malts, three of which can be steeped, but brown malt needs to be mashed. None of the specialty malts contain enzymes, so we have to add in some pale malt to the partial mash; an amount equivalent to the brown malt, 0.5 lb. will do the job. So, using the *BYO* recipe standardization numbers, the gravity points we shall get from the partial mash are as follows:

2-row Pale malt = 0.5 x 24 = 12
Crystal malt = 0.5 x (34 x 0.65) = 11
Chocolate malt = 0.5 x (34 x 0.65) = 11
Brown malt = 0.5 x (35 x 0.65) = 11
Black malt = 0.25 x (25 x 0.65) = 4
Total points = 49

So, the total gravity points required are 5 x 63 = 315, so points required from extract = 315 – 49 = 266. If we use only LME, then we need 266 ÷ 34 = 7.6 lbs. But let's assume we want to use just 7 lbs. of LME, which gives us in points 7 x 34 = 238. Then points from DME = 266 – 238 = 28 and the weight of DME required = 28 ÷ 45 = 0.62 lb. = 10 oz. Summing all this up we have our new recipe, which I have given in complete form:

Converted Portly Stout
(5 gallons/19 L, extract plus partial mash)
OG = 1.063 FG = 1.015
ABV = 6.3% IBU = 50 SRM = 100

Ingredients
7 lbs. (3.2 kg) pale LME
10 oz. (0.3 kg) pale DME
0.5 lb. (0.23 kg) 2-row pale malt (2 °L)
0.5 lb. (0.23 kg) crystal malt (60 °L)
0.5 lb. (0.23 kg) chocolate malt (400 °L)
0.5 lb. (0.23 kg) brown malt (65 °L)
0.25 lb. (0.11 kg) black malt (550 °L)
13.6 AAU Northern Brewer pellet hops (1.7 oz./47 g) at 8% alpha-acid (at start)
Wyeast 1084 Irish Ale yeast or White Labs WLP004 Irish Stout yeast

Step by Step
Add pale and specialty malts to 3 quarts (2.8 L) water at 160 °F (71 °C), stir well, and heat if necessary to bring to 150–152 °F (65.6–66.7 °C). Let stand 30-45 minutes and strain liquid into boiling pot, wash the grains with 1 gallon (3.8 L) hot water, and strain again into pot. Stir in liquid extract, making sure it is fully dissolved, then do the same with the DME. Make up to 5 gallons (19 L) with hot water, bring to a boil and add the hops. Boil 60 minutes, cool, add yeast and allow the wort to ferment. When secondary fermentation is complete (one to two weeks) bottle or keg, conditioning in the normal way. Note that this assumes an extract efficiency of 65% in the partial mash.

The Real World (II)
It should be obvious that if you had started with the converted version of Portly Stout, you could simply backtrack on the above calculations to produce an all-grain recipe for this beer. One of the reasons why this is easy is that you are swapping pale malt for pale LME and DME. With darker extracts you have to allow for whatever specialty malts may be present in the extract. This presents a great difficulty, since we do not often know exactly what has been used to make the extract, and even when we do, we seldom know in what proportion the specialty malt has been employed. And I am talking about straight extracts here; hopped extracts present a further problem if we don't know what level of bitterness they may contain.

We do have some help here, because the *BYO* October 2006 issue offers the "Ultimate Extract Chart" (see it at http://byo.com/images/stories/extract%20chart.pdf). Using this and our experience of the parameters expected for the style of beer being brewed, it is possible to make a shot at such conversions. From the chart, amber, unhopped malt extracts generally have a similar color level which comes from incorporation of crystal malt in the original extract mash. It's a reasonable guess that they will contain around 10–15% of crystal, which will probably have a color level of 60 °L. So assume your recipe uses only extract, with no steep or partial mash, and you've used 6 lbs. of amber extract to make 5 gallons (19 L) of an English bitter at OG 1.042. Then total points = 5 x 42 = 210. If we replace this with 90% pale malt and 10% 600 °L crystal malt then: (0.9W x 24) + (0.1W x 22) = 210, where W is the total weight of replacement grain or 23.8W= 210, so W = 8.8 lb (4.0 kg). Then weight of pale malt = 8.8 x 0.9 = 7.9 lb (3.6 kg), and of crystal = 8.8 x 0.1 = 0.88 lb. (0.4 kg), which can be usefully rounded to 8 lbs. (3.6 kg) of pale, and 1 lb. (0.45 kg) of crystal, and these will be mashed at 150–152 °F (65.6–66.7 °C).

You can do a similar thing for dark amber extracts, except that there is more guesswork. Most of these again contain crystal/caramel (60 °L) probably at 10–15%, along with chocolate malt or black malt or roasted barley, these latter probably being at a maximum of 5% of the total original grist. Your choice of the high-roasted malts will depend on the style of beer (and its taste!); use only chocolate for a brown porter, black for a robust porter, and black and roast barley for a dry stout, for instance. Some of these are also made using Munich malt in the mash, and if you want a rather fuller flavor in your beer, instead of just pale malt use a 60:40 mixture of Munich and pale malts along with the roasted malts.

Start Converting!
So now that you know the numbers, put your math to use and try converting your favorite extract recipe! BYO

Milling Your Own Grains
Pg. 17

MILLING

One of the most important steps in all-grain brewing doesn't involve water or yeast. Properly milling your malted grains before you start brewing has a big effect on how well your finished beer will come out. If you don't crush the grains well enough, you risk not getting the best extraction. Over-mill, however, and you might end up with a big mess and a stuck sparge. In this section, learn more about what's happening when you run your grains through a mill.

Photo by Charles A. Parker/Images Plus

Milling Your OWN GRAINS

Control your crush for better extraction and lautering

by **Kirk Fleming**

Whether you're all-grain or partial mash brewing or just steeping specialty grains, you'll find that selecting, milling, and using grain has its rewards. In this article we will discuss some things you should know about milling grain before you start brewing.

What the Mill Does

For an efficient mash the grain must be physically crushed and broken apart. The resulting ground meal is called grist. It might seem as if the finer the grist the better, but when the mash is complete the grain has to be separated from the mash liquid. If the grain were ground to flour, separation would be difficult because nothing would flow through the grain bed.

The ideal grain mill breaks the grain into enough pieces so all the contents of every seed can be extracted and converted into simpler compounds during mashing. It also leaves the husks as unbroken as possible. If the husks are left intact, they help keep the ground meal, or endosperm, separated enough to allow flow through the grain bed. The idea is to literally squeeze the malt until it's crushed inside the husk, not to roll it like wheat in a bakery grist mill.

If you're doing a partial mash of a pound or two of grain so that it's fairly easy to separate the mash liquid from the grain using a grain (straining) bag, or if you're just planning to steep specialty grains to add color, flavor, and aroma to an extract brew, the way the grain is milled isn't too important. A good crush becomes a factor when brewing all-grain, where 10 pounds (4.5 kg) of grain can become a real mess if you can't get the mash to flow through it.

Some commercial breweries add rice hulls or oat husks to the mash to help keep the grain bed light and fluffy, especially when using huskless wheat malt. For the average-gravity, 5-gallon (19-L) batch of all-grain beer, however, almost any crush will work just fine as long as the grain hasn't been reduced to flour.

How Mills Work

Huge industrial malt mills have evolved to give a balance between the cost of mill operation and maintenance and the efficiency of the brewing process that results from the mill's use. The main feature shared by almost all mills, whether designed for use by Anheuser-Busch or by you at home, is the use of pairs of parallel metal rollers.

Regardless of the length and diameter of the rollers, the idea is basically the same. The rollers are held parallel in a frame, with a spacing between them that is small enough so no grain can pass between the rollers uncrushed.

Grain mills designed for home use can be placed over a bucket or other vessel (above). Others are designed to be wall mounted.

Photos by Charles A. Parker/Images Plus

The ideal result of milling is to crush the inside of the grains while leaving the husk intact.

Photo by Les Jorgensen

Most mills designed for small scale brewing use a two-roller system. When purchasing a mill, look for a model that will treat the grain gently and can pull the grain into the rollers smoothly in stages.

Industrial mills may use two or three pairs of smooth rollers, each pair spaced differently for each stage of the milling process. Such mills also use screens, conveyors, scrapers, and other design features to separate coarse grist from flour and all grist from the husks.

As you'd expect, the industrial beer brewing giants have to get the most from their malt so the crush is crucial. Pennies count when you're making 50 barrels of beer a minute, and big mill designs make economy and throughput top priorities.

A Mill for You

Of course, you and your local supply shop would prefer a mill costing less than a Malibu beach house. Over the years several manufacturers have built a variety of mills using the two-roller concept. One mill used a single roller held close to a flat, fixed plate, and another popular mill uses two rollers that are purposely not quite parallel. Other differences between the various mill designs include roller size and materials, bearing materials, and grain-hopper size.

Mills priced in the $75 to $300 range are available from several manufacturers. When purchasing a mill, you should look for one that will treat the grain gently. When the rollers of the professional-size mills are reduced to homebrew size, they lose some of their ability to pull the grain into the rollers smoothly and crush grain in stages. Watch out for homebrew mills that automatically grind the grain too fine.

Mill Motorization

The first thing that comes to mind after milling 15 pounds (~7 kg) of grain using any hand-operated mill is, "Let's motorize it."

Although few manufacturers will actually recommend motorizing their mills, you should ask them if they feel their products can be safely motorized and if they will recommend the best way to do it.

The next thing that should come to mind is safety. Some mills can be easily powered in minutes by simply removing the hand crank from the drive roller and putting an electric drill on the drive roller axle. Most drills with ⅜-inch chucks can be used this way, but there are a few details to think about to avoid damaging the mill — or yourself.

First, malt contains some debris. Grain that's been swept up off the floor can contain small stones, for example, and these can get into your mill. When they do, they get crushed, something breaks, or the mill stops cold. In industrial equipment where heavy rotating components such as flywheels are mounted on shafts, the two are often keyed together with a soft metal pin. If something causes the shaft to lock up, the flywheel shears the pin and continues to turn rather than breaking the shaft.

You can mimick the shear pin by wrapping a strip of plain paper over the shaft of the drive roller, then putting the wrapped shaft in the drill chuck. Tighten the chuck by hand (not by wrench) just enough to turn the mill when fully loaded. If anything locks up the mill, the drill chuck will slip on the roller shaft.

Also, be aware of the huge difference in the available torque of various electric drills. Some expensive industrial drills produce enough torque to seriously hurt you if something brings them to a sudden stop.

When adding motors, power tools, and electricity to the brewing process, you need to think safety for yourself and others. An electric drill left plugged in and lying on the floor may be a minor threat to young children; a motorized grain mill left plugged in and mounted at bucket height may be a serious hazard. Think about what you're doing and about what happens when fingers or clothing get caught in gear-driven machinery. Because brewing also usually means there is water nearby, pay careful attention when using electricity to motorize a mill.

When grain is milled in bulk using a powered mill, a tremendous amount of grain dust can be generated. Besides the risk of contamination of your beer caused by uncontrolled dust, a cloud of dust in the air can be an explosion hazard. Try to ventilate the milling area if you're generating a good deal of dust, and avoid flames or sparks. This may not be a real problem for the average amateur brewer, but don't take chances, especially if you decide to brew large or multiple batches.

Milling the Grain

If your supply shop already has a mill set up for customer use, then you may be a very lucky brewer. Some stores have poorly-mounted Corona mills that may be worn and difficult to handle or inconveniently located in high-traffic areas. Other stores may have permanently mounted, motorized roller mills set up directly under the grain scales. Either way, you'll have to decide whether you want to use the setup at the store or buy a mill for yourself at home.

To get the most from any mill, mount it in a convenient location. Some mills are designed to be clamped to a workbench, and others are made to sit on top of a 5-gallon (19-L) plastic bucket (see photo above and on page 17). In either case a sturdy set-up that allows one-handed operation of the mill is ideal. Workbenches and tables

can be modified easily to both support the mill and to allow the grist to fall into a receiving bucket underneath.

An important point to always remember: Mill your grain in a location as far as possible from where you'll be chilling your wort and fermenting it. Grain dust is rich in bacteria — bacteria that can contaminate beer quite easily. You may have noticed in brewpubs and microbreweries that the grain storage and milling room is usually separated and sealed off from the brewing room. Often the grain is milled, mashed in, and piped directly into the mash tun. At home, don't mill the grain anywhere near the kettle in which you'll be chilling your wort.

If you choose to buy a mill for use at home, you may also want to think about the extra cost of scales for weighing bulk grain. You can weigh out enough whole grain at your supply store for one batch and mill it at home, but you may want to buy enough grain for several batches of beer and mill it as needed.

An alternative is to use emptied containers (such as coffee cans) of various sizes, measuring your large grain bills by volume. This is actually a good thing. Grain weight changes with moisture content, and measuring by volume from a calibrated container ensures consistent grain quantity from batch to batch. Just fill each of your various containers with grain and weigh the contents using any scale available, marking the weight capacity on the can itself.

Most homebrew supply stores have ample containers for use by grain brewers to measure grain and to store crushed malt temporarily. When purchasing grain for a single batch, all the grains can be weighed and poured into a single container. Then you can load the mill hopper from that container, milling the entire grain bill together.

After measuring out the malt using any convenient technique, pour the grain into the mill hopper. Some mills come with large-capacity hoppers that hold as much as six pounds of malt, and your store may have modified its mill to hold even larger amounts.

If the mill is motorized, start it up; otherwise, start cranking. Mill only the grain you're going to use, if possible. This is like grinding coffee beans — the coffee stays freshest in bean form. If you mill too much and just can't use it all, seal the remaining crushed grain in a large, plastic, food-storage bucket until it's needed.

Try Before You Buy

If you're ready to get into brewing from scratch or just want to use some specialty grains in an extract beer, then you're ready to try crushing some grain. Make a phone call or two, and find a supply shop that already has a mill set up for customer use. Find out what mill they're using, and stop in and give it a try. Whether you mill at home or at the store, you're sure to enjoy your beer even more after adding grain to the picture. BYO

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MASHING

You've got the equipment, you've milled your grains — now it's time to get down to the crux of all-grain brewing: Mashing. During this stage, your grains are mixed with hot water to break down the carbohydrates inside into fermentable sugars. This process also creates proteins and some unfermentable sugars that affect your finished beer, including flavor, body, head retention and aroma. In this section, we will explore the different methods for mashing, how to improve your process and an easy way to perform an all-grain brew day.

Photo by Charles A. Parker/Images Plus

MASH Programs

Single infusion, step mashing, decoction — and beyond

by **John Oliver**

The mashing process is the key to all-grain brewing. During the mash, hot water breaks down the long-chain carbohydrates and proteins provided by malt into simpler, smaller units that serve as food and nutrients for yeast during the fermentation process. Furthermore, the proteins and sugars that are created also affect the body, head retention, aroma, and flavor profile of the finished beer.

There are three basic mashing styles, usually referred to as infusion, temperature program or step, and decoction. Within each of these mashing styles there are subtle variations in techniques that offer myriad combinations for creating sweet wort from grain and water.

Any mash program will likely result in a satisfactory conversion of starches. But to determine which mash program is the best particular one for you and the beer you are brewing requires a little bit of knowledge about how and why each of these styles evolved and its effect on the finished beer.

It is also important to realize that while certain beer styles are created most easily by using the appropriate mash program for that style of beer, historically many of the characteristics of the styles in question evolved as a result of the mashing techniques used, not the other way around. Particular mash styles evolved in response to three major variables: Equipment, technology, and ingredients available. This is where you should begin when determining which mash style will work best in your own brewing,

Single Infusion

In the single-infusion mash a known quantity of water at a known temperature is combined with a known volume of grain at a known temperature. Through the use of temperature charts or formulas, this results in a very consistent method of obtaining repeatable mash temperatures that are accurate within a few degrees. By shifting variables such as the temperature or volume of the strike water (the water into which you mix your grains), the final temperature of the mash can be adjusted up or down.

Advantages: This style of mashing is the simplest, requires the least amount of additional equipment, and uses a less expensive vessel. As such, it is usually the style used by homebrewers when they first make the move to all-grain or partial-mash brewing. Since heat is not applied directly to the mash, it is efficient to mash and lauter (remove the wort from the grains) in the same vessel. This mash/lauter tun combination can be as simple as a plastic bucket fitted with some form of false bottom and perhaps insulated to help maintain conversion temperatures as

> “Infusion mashing was attractive to early brewers. Only one vessel was required to be heated.”

accurately as possible for the duration of the conversion process.

Minor adjustments to the strike and rest temperatures can be made by adding small amounts of cold or hot water to adjust a degree or two up or down. Conversion usually takes 30 to 60 minutes, so there is not as much time added to the brewing process as there is with some of the other mash programs such as step or decoction. Once the infusion of mash and water is complete and a consistent rest temperature is achieved, very little attention is required and the brewer is free to perform other activities such as cleaning, sanitization, or household chores to help speed up the rest of the brew day.

The lack of special equipment required for single infusion mashing also makes this the mash program of choice for the majority of small brewpubs and homebrewers today.

Disadvantages: There are primarily enzymes at work in the mashing process, and each one has its own optimal temperature and performance range. Manipulation of these different enzymes also provides a different character to the sweet wort and hence, the finished beer. Since the strike temperature is going to be pretty close to the rest temperature of the mash, most infusion mashes are done at a compromise temperature usually somewhere around 147 to 156 °F (65 to 69 °C). This results in a relatively fixed fermentability level; as a result, mash efficiency, or the measure of sugars produced in the mashing process, usually suffers.

The inability to mash out (raise the mash to a temperature of 170 °F/77 °C to inactivate enzymes and decrease wort viscosity) further reduces the solubility and increases the viscosity (its thickness compared to water) of the wort, further decreasing mash/lauter efficiency. Since the mash will take place at a compromise temperature, it is imperative that only highly modified malts with a well-developed level of enzymes are used. This will help maximize the yield of the mash.

Photos by Charles A. Parker/Images Plus

History: Infusion mashing was attractive to early brewers. Only one vessel was required to be heated. This one kettle could do multiple duty by heating the strike water, then later be used for boiling the wort. Early infusion mashes most likely did not incorporate any form of sparging, the process of spraying the grains with hot water to rinse as much malt sugar as possible. The sweet wort was simply run off into the kettle. The mash might have been saved to later be reinfused with more strike water for a second run-off of a weaker style of beer.

Later, as sparging was incorporated into the lautering process, the sparge water or hot liquor could be heated in the kettle and transferred to an insulated holding vessel until it was required for sparging. Almost any style of beer can be produced from any mash program, but those styles of beer such as British pale ales, stouts, porters, bitters, and brown ales that usually use highly modified pale malts are good candidates for single-step infusion mashing.

Step Mashing

Temperature program or step mashing differs from single-infusion mashing in that numerous temperature rests can be incorporated in the mash schedule. Resting the mash at a series of successively higher temperatures allows a wider variety of enzymes to work within their own optimal temperature ranges for a set amount of time. This results in more control for the brewer over the final characteristics of the sweet wort and the ensuing beer.

You can raise the temperature of the mash through the use of a mash tun to which heat can be applied or through repeated infusions of hot water to successively raise the mash to the appropriate rest temperatures.

The beta-glucan rest occurs at 118 °F (48 °C) to reduce wort viscosity caused by gummy beta-glucans. This is especially important when using flaked barley, oats, and rye, as well as lightly modified malts.

The beta-amylase rest occurs at 135 to 140 °F (57 to 60 °C) to increase wort fermentability, while the alpha-amylase rest takes place at 158 °F (70 °C) to "convert" the mash.

Two rests no longer used by most commercial brewers are the acid rest at 110 °F (43 °C), which was formerly used to adjust mash pH, and the protein rest at 122 °F (50 °C), which current research indicates has no value.

Advantages: In this form of mashing, the brewer has a greater impact on the finished beer than he or she does using single infusion. Varying the times spent at the various optimal rest temperatures — or deleting certain rests entirely — dramatically varies the resulting sweet wort, even if the grain bills are identical. Also, since a wider variety of enzymes can be brought into play at their optimal temperatures, mash efficiency (the percentage of sugars from the grain that make it into the wort) usually improves. As a result, the degree of modification of the grains is not as critical, and hence a wider variety and quality of grains can be used. If you use a step-infusion program, you may not need equipment in addition to that used for the single-step infusion, providing the mash/lauter tun is large enough to hold the full final volume of the mash.

Disadvantages: Because a wide variety of rests and enzymes can be incorporated into a step-mashing program, it is important to have a clear understanding of what the performance characteristics of the various enzymes are and how they affect the finished product. You can refer to most brewing texts with an extensive section on all-grain brewing for a more complete understanding of these temperature rests and the enzymes at work (but be prepared for a little chemistry).

The mash temperatures can be raised in one of two ways. If successive infusions of hot water are introduced to raise the temperature of the mash, the mash usually will start out relatively thick and by the last step be rather thin and watery; this reduces the specific gravity of the wort and can be detrimental when brewing stronger beers. If you raise the temperatures by directly applying heat to the mash, a mash tun that can be heated is required.

Because the purpose of step mashing is to incorporate additional rests, it usually takes more time overall than the simpler single-infusion technique. Also, most single-infusion mashes benefit from being left alone during the rest period, allowing the brewer the time to perform other duties such as heating water or sanitizing equipment. But a step-mash program requires continual monitoring of the mash and stirring to ensure that each rest is accurately reached and that the temperature is even throughout. In short there are more variables to be controlled and taken into account, and there is more work to do. However, many styles of beer that focus on malt complexity, such as the various Belgian strong styles, and styles incorporating wheat in the recipe can benefit from a step-mash program.

Decoction

Decoction mashing is a form of step mashing in which the brewer removes a portion of the mash, usually about one-third of the thickest part, leaving behind as much of the liquid as possible. This thick decoction is placed into a separate kettle, where the temperature is raised until the decotion boils. Then the decoction is reintroduced into the main mash, thereby raising the temperature of the whole mash to the next step. This entire process can be repeated as many as three times to incorporate the same temperature rests discussed in step-mashing.

Advantages: When the thick grain portion of the mash is boiled, a physical breakdown of the starches and proteins results, giving the enzymes present greater access to them. This results in a greater conversion rate (more starches are converted to fermentable sugars) than with other mash methods, particularly when low-modified or undermodified malts such as Pilsner and lager malts are used.

In addition, many homebrewers feel that the best way to produce very malty and complex brews is to use decoction mashing.

Because the boiling point of the decoction is fixed, its reintroduction to the main mash results in surprisingly consistent temperature rests. This helps to avoid the tendency to overshoot temperatures when step mashing using a heated mash tun to raise the temperature.

Disadvantages: This is by far the most laborious and time consuming of the mash programs. A typical decoction mash program can easily be two hours or longer. Extra kettles are almost mandatory, as is a high-output heat source that can be accurately controlled to prevent scorching the mash. The decoction and main mash requires constant monitoring and stirring to ensure accuracy and to prevent any scorching or burning of the mash.

History: This style of mashing evolved in Europe, where the malts available at the time were less modified than British malt. The decoction method allowed brewers to consistently perform multi-temperature mashes before the advent of the thermometer and to use the boiling methods to achieve these various temperature rests all physically degrade cell walls present in undermodified malt. This method most certainly developed empirically. Not only did it pre-date the thermometer, it also pre-dated our modern understanding of enzymes and malt modification.

Combination Techniques

In addition to these three methods, many commercial breweries that incorporate a lot of cereal adjuncts in their recipe formulations use a form of mashing that is a combination of decoction and infusion techniques.

To use large amounts of adjuncts such as corn or rice effectively, these unmalted grains must first undergo a process called gelatinization. The hard, starchy interior of the grain is cooked down to make it available to the enzymes in the malted barley for conversion.

After undergoing this cooking process, the adjunct cereal grains are then infused into the main mash. They help to raise the temperature of the mash while at the same time contributing large amounts of gelatinized starches for conversion.

In such a process it is common to employ six-row pale malts both for their high levels of enzymatic potential as well as for their ability to aid in the lautering process due to a greater husk-to-starch ratio.

Mashing Techniques

Keep in mind with all mashing programs that the natural process of converting starches to sugars takes place over a range of temperatures and not just at one set point. No matter which style of mashing best fits your equipment and ingredients, fluctuations of a few degrees will probably not ruin the resulting beer. They likely will make it only slightly different than what you might have been searching for.

Keep good notes when mashing (and throughout your brew day in general), taking care to record mash temperatures, water temperatures, and mash rest times. In doing so you will have a history of what worked and what did not, which will provide a wide influence over the finished beers you create, and also a great reason to keep trying new mashing techniques. BYO

MAKING the Most of Your MASHES

Refine your mashing variables and fine tune your technique

by **Chris Colby**

As mentioned in the first article of this issue on page 5, mashing is just soaking crushed grains in hot water, then draining off the unfermented beer. The ancient Sumerians supposedly discovered the process by accident, and brewers throughout the centuries honed the process to what it is today. Most homebrewers roughly retrace this historical sequence when learning to mash — they don't exercise a lot of control over their first few mashes, but gradually they fine tune their process.

In this article, we'll discuss the refinements you can make once you've got your first few mashes under your belt. We'll describe the variables that have the biggest impact on your finished beer and also touch on some of the practical aspects of being an all-grain brewer.

Buying and Storing Grain

One benefit of all-grain brewing is that your per-batch cost is lower than in extract brewing. (Of course, this is partially offset by the one-time cost of new equipment.) You can save even more money if you buy some of your grains by the sack. A sack of grain usually weighs either 50 or 55 lbs. (23 or 25 kg) and your cost per pound is less than a buck. Many all-grain homebrewers buy a sack of base grains, then buy the specialty grains for each batch as they go. Keep in mind, though, that malt is a food product and does go stale over time so buy what you will use.

Also remember that rodents and insect pests would love to get into your grain, and they will if you don't store it properly. Many homebrewers buy a 55-gallon (208 L) plastic garbage can with a sealable lid to store their grains in. This will keep pests out and — if located in a cool, dry place — your (uncrushed) grains should keep for about a year.

The Crush

As discussed in the section of this issue about milling on page 16, one thing you can do that greatly affects your brewing is to get a good crush. The degree your malt is crushed affects many aspects of your mash, and the wort you yield from it.

The fineness of a crush varies from the grain kernels barely being disturbed to the grain kernels being ground into a uniformly fine powder. The optimal crush lies between these two extremes. The finer you crush, the higher your extract yield. However, with finer crushes, it is harder to collect your wort as the grain husks are too small to act as an efficient filter. In addition, the more pieces the grain husks are broken up into, the more tannins and other unwanted husk components will end up in your wort. Ideally, you want to crush finely enough that you

"The degree your malt is crushed affects many aspects of your mash, and the wort you yield from it."

Photo by Les Jorgensen

Paying attention to the details of your all-grain brewing — from milling through mashing — will improve your finished homebrews.

get a good extraction efficiency, but coarsely enough that you can lauter with ease and minimize off flavors and astringency. So how do you do that?

The biggest variable affecting your crush is your mill gap — the space between the rollers in your grain mill. It would be nice if there was an optimal mill gap, but the best gap size depends on the grains you are milling and — to a lesser extent — the speed at which the rollers on your mill rotate. In general, however, a mill gap between 0.035 and 0.050 inches (0.89 and 1.3 mm) is thought to be a good, all-purpose setting for barley malt.

A second variable affecting your crush is the speed that the rollers rotate. The rollers on hand cranked mills rotate much slower than the rollers of commercial mills. (Their average speed is 400 RPM, for the optimal 9.8-inch (250-mm) diameter rollers). As such, hand cranked mills crush more coarsely when set to the same gap size. In contrast, home malt mills powered by a portable drill greatly exceed the proper speed and may crush too finely. To get the proper grain mill speed, you need to get a motor and control the speed with "pulleys," more properly called sheaves.

Most homebrew malt mills are suboptimal in one or more respects when compared to full-size commercial mills. Most are either hand cranked or drill powered (i.e. rolling too slowly or too quickly). The diameter of the rollers on homebrew mills is frequently smaller than on commercial mills. And, many mills have a fixed gap, so the mill cannot be adjusted for different grains. Still, most all-grain homebrewers manage to get crushes that yield extract efficiencies in the same ballpark as most brewpubs or microbreweries. How is this?

You can judge the quality of your crush by examining the grain discharged from the mill or by brewing with it. What you want to see is few or no uncrushed kernels, plenty of kernels broken into two to four pieces and a minimal amount of flour. If you think your grain looks like it is crushed too finely — or you get high efficiencies, but stuck mashes and astringent beers — you have a couple options. You can switch to a larger gap setting, if your mill is adjustable, or start hand cranking, if you were using a drill to power your mill.

Conversely, if your grain looks undercrushed — or you get low efficiencies, but have no problems lautering (even when you run the wort off quickly) — you can set a smaller gap or motorize your mill.

In the case of undercrushed malt, you can also mill the grain twice. Even if you have a non-adjustable, hand-cranked mill, a second run through the mill will break up the kernels a bit further. Of course, the second crush can be a bit of a pain, as the grain won't flow as easily in the hopper as it did when it was whole. So, the second crush may take considerably longer than the first. But, it can be worth it if you are brewing a big beer (and need all the extract efficiency you can get) or if your efficiency is very low.

The point is, although we homebrewers typically use mills that commercial brewers would deem sub-standard, there are workarounds we can use to get a decent crush. These operations would be impractical for commercial brewers who crush much larger amounts of grains and, for economic reasons, need to do so quickly (thus ruling out hand cranking or milling the grain twice). But, when milling less than 20 lbs. (9.1 kg) of grains on Saturday morning, it's usually not that much of a hassle.

Temperature Differences

Everyone knows that temperature is important in mashing. However, one temperature-related aspect of mashing is usually left for the homebrewer to figure out on his own — temperature consistency and stability.

It's fairly easy to end up with temperature differences in your mash. Variables that increase the potential for temperature differences include: Direct heating of the mash, thicker mashes, less stirring of the mash, large initial temperature differences between your grains and strike water and large temperature differences between your target mash temperature and your mash tun.

If you have a mash tun that you can heat, be sure to stir well when doing so. You may even want to stir for a minute or so after you turn off your burner as heat can continue to flow into the mash through the metal near the burner.

Most homebrewers mash fairly thickly, with mash thicknesses around 1.25 quarts of water per pound of grain (2.6 L/kg or a 2.6:1 ratio) being popular. However, if you are going to be heating the mash, you may want to go with a bit thinner mash. For example, if you were doing a heated step mash, a mash with a thickness around 1.9 qts./lb. (4 L/kg, or 4:1) would be easier to even out than a thicker mash. (This is because water conducts heat better than grain solids.)

When mashing in, your crushed grains are going to be much cooler than your strike water. Ideally, mixing the two should yield a mash right at your target temperature. For grains stored at around room temperature, heating your brewing liquor 10–11 °F (5.5–6 °C) over your target temperature will get you in the right range (assuming a roughly average mash thickness). Some software packages will calculate your ideal strike water temperature based on temperature and weight of your grain and target mash thickness. You can also determine the correct temperature by trial and error. Note your strike water temperature and initial mash temperature for two or three brewing sessions and you'll quickly get a good feel for what your strike water temperature needs to be. The closer your strike water is to the correct temperature, the quicker your mash in will be. Also, a little stirring should quickly even out any temperature differences in the mash.

The temperature of your newly mixed mash can potentially be affected by the temperature of your mash tun. Ideally, you want to heat the mash tun to right around your target mash temperature prior to mashing in. Filling your mash tun with brewing liquor heated to a few degrees above your target mash temperature should do the trick. Let the water sit for a couple

minutes, then return it to your hot liquor tank to be used later as sparge water. If you mash in a non-heated mash tun, the sides of your mash will quickly become cooler than the middle of your mash.

Temperature Stability

Once you are mashed in, your grain bed will start losing heat. The better insulated your mash tun is, the less heat loss you'll suffer. Temperature losses will be greatest near the edges of your vessel. You can insulate your mash tun simply, for example with towels, with a fitted "jacket" that goes over the vessel or by wrapping it in fiberglass insulation. Even if your mash vessel is fairly well insulated to begin with — for example, if you mash in a converted picnic cooler — adding a little extra insulation will help you retain more heat.

So essentially, differences in mash temperature may exist initially within the mash and can form during mashing due to heating or cooling. In all cases, stirring thoroughly will even out the mash temperatures.

However, as you need to open your mash tun to stir, you'll also lose heat each time you do. As such, you'll want to add some heat each time you stir. If you are mashing in your kettle (or have a heatable mash tun), just heat the mash as you stir. If you can't apply direct heat, you'll have to add near-boiling water. In the latter case, you should only open the mash vessel and stir if you suspect significant temperature differences exist. The only way you'll have any idea if this is the case is to take good notes the first few times you mash. Take the temperature at several places once you are mashed in. Stir until the temperature differences even out and seal the mash tun. After 15 minutes, open up your mash vessel and take the temperature near the middle and near the edges, then add some boiling water and stir to bring the temperature back to your original target. If the temperature changed little and showed little differences from the middle to the edge over 15 minutes, next time let the mash rest longer before opening it up. If you're losing significant heat in under 15 minutes, you'll definitely want to insulate your mash vessel to a greater degree.

Photo by Charles A. Parker/Images Plus

Once you mash in, your grain bed will start to lose heat. Wrapping your mash tun with a fitted "jacket" will reduce heat loss, or you can use an insulated cooler as a mash tun.

On a 5-gallon (19 L) scale, try to keep your mash within 3 °F (1.5 °C) of the target temperature and keep temperature differences under 2 °F (~1 °C). Many homebrewers will mash in the kettle and have a fitted "sleeve" to put over it for insulation. To keep within 3 °F (1.5 °C) target, you may need to open up, heat and stir every 20 minutes. You'll have to decide for yourself what amount of temperature deviance you are willing to put up with. The tighter the control you seek, the more you are going to have to monitor, stir and heat your mash.

Also, if you are adding hot water to keep your temperature up, you may end up thinning the mash too much or running out of room in your mash vessel.

Wort Collection

Once the mash is over, the mash out has taken place and the wort is recirculated, wort collection begins. One factor that greatly affects the quality of your beer is how much wort you collect. The first bit of wort you run into your kettle is high in gravity (up to SG 1.100, depending on your mash thickness) and contains no undesirable elements extracted from the husks. As you continue to run off wort and rinse the grain bed with hot water (sparge), the gravity of the runnings drops and, at some point, the extraction of unwanted husk materials begins. Thus, for every unit of grain you mash, there is a volume of wort you can collect that yields the maximum amount of extract before wort quality suffers.

To find your proper volume of wort to collect per weight of grains mashed, you need either a calibrated hydrometer or a pH meter. Measure the specific gravity or pH of the runnings as you collect the wort. When the specific gravity drops to 1.010 or the pH rises to 5.8, stop collecting wort and make note of the volume of wort in your kettle in your notes. Divide this volume by the amount of grains you mashed. For example, let's say you mashed 12 lbs. (5.4 kg) of grains and collected 6.5 gallons (25 L) of wort before stopping. This means that you collected 0.54 gallons of wort per pound of grain (4.5 L/kg). Finding this ratio on your system will allow you to plan ahead of time how much wort to collect from any future grain bill by multiplying the weight of your grains by this number. From this, you can figure if you'll need to add water to your wort, based on your expected boil time. This may be necessary when brewing low-gravity beers from small grain bills. On the other hand, with strong beers — brewed from correspondingly large grain bills — you can use this calculation to predict how long you will need to boil to reduce your wort volume. BYO

Control Mash Thickness

Control mash thickness by varying the ratio of water to malt. Perfect this technique to tame the enzymes that cause important reactions in the mash, influence fermentability, and affect beer flavor.

On the surface the brewery mash appears to be a simple mixture of malt and water. When held hot for a period the mash begins to thin, producing a cloudy, semi-sweet liquid, then transforming into a mixture of clear, intensely sweet wort and spent grains.

Beyond these macroscopic changes lie important biochemical reactions that convert the starch found in the grain into sugar. Malt enzymes act as catalysts, in a sense causing these reactions.

Mashing begins when malt solids dissolve. These solids are primarily made up of starch but also include a significant portion of proteins. Included among the proteins are the catalysts, malt enzymes. The enzymes latch onto mainly starch and smaller carbohydrate molecule chains in a mash, bringing about a chemical reaction. These starch and carbohydrates are called substrates, because they are broken down by the protein-based enzymes during the reaction.

Smaller proteins, smaller beta-glucans (viscous gums that contribute to wort viscosity), sugars, and dextrins (unfermentable carbohydrates that add body to beer) are the products of enymatic attack and their parent compounds — proteins, beta-glucans, and starch — are called enzyme substrates.

Taking Charge

A brewer's challenge is to let nature travel its free-wheeling road but in a controlled environment. Mash temperature, mash pH, water chemistry, enzyme concentration, substrate concentration, and product concentration are the mash variables that can be easily controlled.

Mash temperature has a great influence on which enzymes are active, because enzyme activity depends on temperature. Temperature also can cause enzymes to denature and permanently lose their catalytic activity. The principle enzymes involved in mashing all have different optimal temperatures.

Like temperature, mash pH affects enzyme activity. Enzymes must be in specific pH ranges to be active catalysts. In general the mash pH should fall between 5.2 and 5.4, because the enzymes of interest to brewers are active in this range. With most brewing waters and malts mash pH naturally falls in this range, so pH is not one of the mash variables that demands vigilant monitoring.

Other attributes that affect enzyme action are the concentrations of enzymes, substrates, and their products. These features are very important, because they influence the rate at which starch is broken down in the mash. As this reaction proceeds, the concentration of products (such as smaller carbohydrates) begins to build up and can slow down the reactions occurring in the mash. In addition to the speed or rate of the reaction, concentration can affect enzyme stability.

What Does It All Mean?

The concentration of enzyme, substrate, and product fall under the umbrella of "mash thickness." Mash thickness is the weight ratio of water in the mash to malt in the mash.

Since one liter of water weighs one kilogram, mash thickness is easily determined when malt is measured in kilograms and water is measured in liters. For example, if 12 liters of water go into a mash with four kilograms of malt, the mash thickness — or if you are British, the liquor to grist ratio — is 3:1. Although this is the most common way of expressing mash thickness, some brewers use the ratio of malt to water and express the ratio as a percentage. In the previous example the mash thickness could also be called 33 percent malt. In both cases it is simply the weight ratio of water to malt.

Although there are infinite mash thicknesses to use in brewing, three generic ranges of thickness are used in practice. These are the "thick mash," the "medium-thick mash," and the "thin mash." These terms do not define thickness in absolute terms, but they do convey some important messages to the brewer.

Thick Mashes

In a thick mash the concentrations of enzymes, substrates, and products are all high, since there is a bunch of malt in a little bit of water. In numerical terms a thick mash is anything less than about 2.5 parts water to one part malt. The rule of thumb for mash thickness quoted in many homebrewing books is one quart of water per pound of malt; as a weight ratio that is 2.1:1. That is a pretty darn thick mash!

The thick mash has certain ramifications. The most striking feature is that it provides substantial protection to the enzymes present in the mash. In other words the enzymes are less likely to be denatured (stripped of qualities that allow it to catalyze the desired reaction) by high temperatures. This feature allows beta-amylase and alpha-amylase to work in concert, which is handy for a single-temperature mash. Without the protection of the thick mash, beta-amylase could be quickly denatured and the resulting wort would be predominated by the products of alpha-amylase action. Such a wort would have a high concentration of unfermentable carbohydrates. The resulting beer would have a higher terminal gravity and lower alcohol content than a beer made from a more fermentable wort.

Thick mashes do have obvious advantages, but there are some problems. Water is required to break down starch. Water is chemically inserted between the glucose molecules of the starch polymer during hydrolysis (the enzyme-directed breakdown of starch) and a shortage of water can cause incomplete breakdown of starch during mashing. Although mashes are rarely thick enough to cause incomplete starch conversion, very thick mashes can slightly decrease wort fermentability.

A less subtle result of thick mashes is noticeably lower extract yield. Thick mashes simply cannot bring all of the malt starch into solution. Although decreased extract yield is not going to send any homebrewer to the poor house, commercial brewers are not very fond of this side of the thick mash.

The last major problem with thick mashes is the high concentration of starch breakdown products. This feature is easy to spot when the specific gravity of the first runnings from the mash is taken. In thick mashes the first running gravity is usually greater than 20 °Plato (1.078). These products can interfere with enzyme action, resulting in what is called product inhibition.

Product inhibition may serve to control the millions of enzymatic reactions occurring every second in the human body, but it is not the brewer's best friend. In the mash, product inhibition can lead to incomplete starch breakdown and decreased extract yield and fermentability.

Some enzymes, especially proteases (enzymes that attack protein), are very sensitive to product inhibition and are not very active in such environments. Periodically stirring a thick mash can help to alleviate product inhibition, since stirring distributes the enzymatic products that naturally accumulate near enzymes.

Medium-Thick Mashes

If a mash thickness less than 2.5:1 is thick, then a mash thickness between 2.5:1 and 4:1 should be medium. In practice a thickness of about 3.25:1 best captures the feel of the medium-thick mash. These mashes retain many advantages of the thick mash but few of the downsides. Additionally, mashes in this range of stiffness are easy to move around. This feature is important when conducting stirred, multi-temperature mashes as it allows for easier mixing and better heat transfer than a thick mash. These mashes are easy to pump, if required. Commercial breweries, for example, pump the mash from the mash vessel to the lauter tun.

Although thinning out the mash makes the enzymes less concentrated and hence more susceptible to temperature denaturation, this only occurs if the mash is conducted at an unacceptably high temperature. In general an infusion mash temperature of 150 to 155 °F in a medium-thick mash allows sufficient beta-amylase activity before rendering it inactive (beta-amylase usually begins losing activity above 149 °F).

After beta-amylase is denatured, alpha-amylase remains active because it is less sensitive to these temperatures, it can survive up to 170 °F. If multi-temperature mashing is used, then these problems are alleviated, regardless of thickness. But the thinner mash makes stirring easier.

The thinner mash also decreases the concentration of substrates and products. This minimizes the effects of product inhibition, the slowing of chemcial reactions caused by build-up, and also eliminates the loss of extract associated with very thick mashes.

In general the medium-thick mash provides for good enzyme activity, allows for easy stirring and pumping, will produce a wort with a high degree of fermentability, and produces a good extract yield from the malt. However, if a mistake is made by mashing in too hot, then the chance of causing irreversible enzyme loss is higher than if the same mistake is made in a thick mash.

Thin Mashes

Thin mashes are any mashes where the water-to-malt ratio exceeds 4:1. Like the medium-thick mashes, thin mashes are easy to move around and provide excellent heat transfer. They also give high extract yields, since the malt solids are easily dissolved.

The problem with thin mashes is enzyme stability. Enzymes are less stable in a thin mash and denaturation can become a real problem. The enzyme of concern is beta-amylase, since there is a limiting supply of beta-amylase in comparison to alpha-amylase. If beta-amylase denatures too quickly, then the resulting wort will have a decreased fermentability.

Some multi-temperature mash schedules suggest adding very hot water to increase temperature. This technique thins the mash and can render enzymes, especially beta-amylase, inactive when they are most needed. You may not like the results of using this method unless you want to limit fermentability.

~ Ashton Lewis

BREW in a BAG

Get mashing with less equipment and steps

by **Derrick Hakim**

Brew-in-a-bag (BIAB) is the easiest and most economical way for an extract brewer to step-up into all-grain brewing. What makes this method (which was made popular by Australian homebrewers) unique is that you can basically do with one kettle what traditional all-grain brewers do with three separate and distinct vessels. With a single-large brew kettle, and the help of an inexpensive grain bag, you have the equipment that's needed to brew your first all-grain masterpiece.

Why Would You Want To Brew BIAB Anyway?

If you are considering BIAB, there are a few reasons why it is a good option.

1. You want to get into all-grain brewing, but at a lower cost.
2. You don't have enough space for the additional vessels required for a full all-grain set-up.
3. You want to have more control of your ingredients right from the start.
4. You don't want to clean much more equipment than you already do with extract brewing.

The Cons of BIAB:

There are a few considerations to keep in mind with BIAB, however.

1. You'll need a larger kettle than you most likely have for extract brewing, to brew a standard 5-gallon batch.
2. That kettle's going to need a valve to move your cooled wort into your fermenter. You will be transferring about 5.5 gallons (21 L), so either invest in a health club membership or just install a ball valve on your kettle instead.
3. It takes more time to create your own wort rather than opening a couple containers of extract. About three more hours will be added to the brew day.
4. Compared to traditional all-grain brewing, your pre-boil efficiency can be lower. Extract brewers don't calculate pre-boil efficiency since they don't start their process from the grain. But when you do, you want a measurement of how well you did in extracting what sugars were available to you, from those grains, and what you actually collected in your wort. This will help you become more consistent from batch-to-batch.

Some BIAB brewers compensate by adding more grains to the grain bill, having their grains double-crushed, mashing longer, performing a mashout to aid in efficiency, or a combination of these. Currently, I have my grains double-crushed, mash for 90 minutes, and perform a mashout for 10 minutes at 170 °F (77 °C).

> "You can basically do with one kettle what traditional all-grain brewers do with three . . ."

Photos by Derrick Hakim

Brew in a bag (BIAB) is a simple way to brew all-grain recipes all in one brew pot.

Equipment Needed For BIAB

Large Brew Kettle

This one single vessel is going to act as the hot liquor tank (HLT), mash/lauter tun, and brew kettle from a traditional all-grain system. If you are going to brew a typical 5-gallon (19-liter) batch, you're going to need a good sized kettle and a way to heat a lot of water.

In extract brewing, you're typically working with 2 to 3 gallons (7.5 to 11 L) of water in your kettle and adding the concentrated wort to your fermenter, where it's diluted with additional water to reach your 5-gallon (19-L) batch size. This is very manageable with a 5-gallon (19-L) pot and most kitchen stoves, although a larger pot will give you more space.

With BIAB, we need to have the full volume of water required to mash the grains, boil the wort, fill our fermenter with about 5.5 (21 L) gallons of wort, and account for all the loss along the way, so we can package our target 5-gallons (19 L) of beer. Depending on your grain bill, that's going to require a 10+ gallon (38+ L) kettle and a burner with plenty of BTUs. The larger your kettle, the larger the grain bill or batch size you'll be able to accommodate. But if you go too big, brewing indoors on a stovetop will not be an option, and you'll need a large burner with not only enough BTUs but also a sturdy frame to support all the weight.

My brew kettle was converted from a steam stockpot that's 44-quarts (11 gallons/42 L). It has a removable stainless-steel basket that keeps the grain bag off the bottom of the kettle during heating, and also provides additional support to the bag when it's time to remove the spent grains from the wort. Some BIAB brewers use the steam baskets with simple hoists to raise the bag out of the wort and let it hang over the kettle while it drains off.

If you occasionally want the flexibility and have the capacity to brew indoors, then you won't want to be much bigger than a 10- to 11-gallon (38- to 42-L) kettle, depending on the burners on your stove. I successfully brew 13-lb. (5.9-kg) grain bills with about 8 gallons (30 L) of water, indoors, on our natural gas cook-top with a 17,000 BTU burner. It takes longer to get to temperature, and the boil isn't as vigorous as my propane burner is outside, but it beats brewing only when weather permits.

Large Grain Bag

You can buy these pre-made from any homebrew supply, custom higher quality bags from online sources, or simply make your own. Most are coarse mesh, made of nylon, and can be had for less than $8.00. They are typically 24-in. x 24-in. (61-cm x 61-cm) or 24-in. x 36-in. (61-cm x 91-cm) in size.

If you're looking for a higher quality-long lasting bag, you can get a handmade polyester bag with reinforced seams, proper stitching, special thread, and sewn-in handles for easier lifting. These are available online for about $35.00 and may be a great option if the other bags just aren't cutting it.

Water Requirements

It is important to calculate the correct amount of water required to get through the entire process from the mash to the finished beer. This was probably the most difficult part for me to get right when I first started using BIAB because your equipment will directly impact the calculations. Most common brewing software now incorporates BIAB in their calculations, which can help a great deal, but you'll still need to know a bit about your individual setup to get it perfected, and that will take some trial and error.

You certainly can use almost any brewing software of your choice that has a BIAB or single-infusion mash option, or one of the many free calculators available online. We will be using a BIAB water calculator that's easy, accurate and free. It can be found, along with links to other great calculators and software, under "Brew Day Prep" at http://BiabBrewing.com.

To get started with calculating our water requirements, you'll need the following basic information to enter into the BiabBrewing.com calculator:

- Finished batch size (gal.)
- Total weight of the grain bill (lbs.)
- Total weight of the hops (oz.)
- Boil time (minutes)
- Equipment boil off rate (gal./hour)
- Expected fermentation trub loss (gal.)

Add the properly-calculated amount of strike water to your brew kettle and heat it to temperature. Use the calculator to convert water depth in inches to gallons. Here I'm using stainless steel hose clamps secured to the handle of a mixing paddle, adjusted to strike water, pre-boil, and post-boil depths.

Once the strike water comes up to temperature, insert the false bottom in your brewpot and insert the grain bag in the pot. Secure it to the pot with some binder clips.

Add the grains to the bag in the kettle, stirring the grains to prevent clumping. If you have a second pair of hands, one person can pour while the other stirs.

Mash the grains for 90 minutes, insulating the kettle to prevent heat loss. A longer mash (as compared to traditional all-grain brewing) can help increase efficiency.

Check the temperature of the mash periodically and stir the grains. Stirring will help with conversion.

When the 90 minutes of mash time is over, remove the insulation from the brewpot, raise the heat to 170 °F (77 °C), stir the mash and cover for 10 minutes.

Once conversion is complete, give the grains a final stir and then remove the grain bag from the brew pot.

Let the wort drain from the bag by setting it on a colander over the kettle or a bucket. When you have collected all the wort, you will proceed with the boil.

- Grain absorption rate (default=0.125 gal./lbs.)
- Hop absorption rate (default=0.0365 gal./oz.)
- Grain temperature (°F)
- Mash temperature (°F)
- Interior kettle diameter (inches)

If you use software like BeerSmith, Brewer's Friend, etc., be sure to set-up your equipment profile properly by editing the default values that most closely match your set-up, or by using more accurate information that you may already have. We're going to use the profile information that I use with my BIAB setup for this example session. Yours will most likely be different, but these figures will get you started.

Information You Need From a Beer Recipe

There is a list of specific information you will need to brew an all-grain recipe with BIAB. To explain this, we're going to look at Northern Brewer's American Wheat Beer all-grain recipe. This recipe calls for a single infusion mash schedule and a mashout. Here's what you'll need to gather from the recipe:

Add Up the Total Grain Bill

4 lbs. (1.8 kg) Rahr white wheat malt
4 lbs. (1.8 kg) 2-row pale malt
= 8 lbs. (3.6 kg) total

Add Up the Total Amount of Hops

1 oz. (28 g) Willamette
1 oz. (28 g) Cascade
= 2.0 oz. (57 g) total

Boil Time

60 minutes

Mash Temperature

152 °F/67 °C

Equipment and Other Information You'll Need

Equipment Boil-Off Rate

You'll have to estimate this number your first time and adjust as you brew each batch. You could get a more accurate starting point by filling your kettle with a measured amount of water, like 5 gallons (19 L). Once it reaches a rolling boil, set your timer for 60 minutes. After the water cools, measure what's left. The difference is your boil-off rate per hour. This should give you a good baseline to start from. For reference and for the calculations in this story, my setup is 0.5 gal./hr.

Finished Batch Size You Want to Bottle or Keg

This is what we want to package, not what's going into the primary. In the case of this recipe, it is 5 gallons (19 L).

Expected Fermentation Trub Loss

This could vary from recipe to recipe, but I usually keep it constant. 0.5 gallons (1.9 L) is what I typically use.

Grain Absorption Rate (gal./lbs.)

This is the amount of water soaked-up by the mashed grains. I typically use 0.125 gallons (0.5 L), but this number is affected by squeezing the grain bag.

Hop Absorption Rate (gal./oz.)

This is the amount of water soaked-up by the hops and hop bags. I use 0.0365 gallons/oz., but like the grain bags I just mentioned, this is affected by squeezing the hop bags.

Grain Temperature

Grab your temperature probe and stick it into your bag of crushed grains to get a measurement on brew day. This will help calculate what temperature to heat the strike water to, so when you add the cooler grains, you'll be close to your mash temperature. For example, when I brewed for this story, my temperature was 71.2 °F (22 °C).

Interior Kettle Diameter

This is great if you have a symmetrical, flat-bottomed kettle and want an easy way to measure your volumes. If you measure your kettle's interior diameter and enter its value, the calculator at BiabBrewing.com will give you the strike water depth (in inches), and how many inches each gallon is in your kettle. You can use a stainless steel ruler, yard stick, or I use stainless steel hose clamps secured on the handle of a long mixing paddle adjusted to these measurements. My interior diameter is 13.625 inches (35 cm).

After you calculate your results, you are ready to brew. Now comes the easy part.

Brew Day

Brew-in-a-bag is very simple once you get the math out of the way. The only difference between this method and brewing with extract is what we do before the boil begins. Get your ingredients and equipment together to begin the mash. Here is what you will need before you start:

1. Brew kettle
2. Large grain bag
3. Thermometer
4. Burner or heat source
5. Mash paddle or long-handled spoon
6. Long stainless steel ruler
7. Five or more binder clips
8. Blankets or other brewpot insulator
9. Kitchen timer
10. False bottom, stainless steel or aluminum colander or basket strainer (to place on the bottom of the kettle to protect the bag from direct heat)
11. Double crushed grains (This will allow us to keep our grain bill as stated in the recipe without adding any extra to increase efficiency. If you order your grains online, put a note in the order form, other wise have your local homebrew supply do it or mill them yourself. I've never been charged extra for double-crushed grains.)
12. All other ingredients needed to complete your brew day

Step 1: Add Strike Water and Heat

Per our calculated results, we need to fill our kettle with about 7 gallons (26 L) of strike water and heat it to about 156.6 °F (69 °C). If you decided to go with the measured route, just fill your kettle to that point (11.2 inches/28.4 cm in this example), otherwise measure your volume with another method. Be as accurate as you can, but don't worry too much about it. Remember, it will be heavy, so it may be best to fill it right on the burner.

Step 2: Insert Bag

Once we reach the strike temperature of 156.6 °F (69 °C), insert whatever you're going to use as a false bottom to keep your bag away from direct heat. This can simply be a metal kitchen colander placed upside down in the bottom of the kettle. Next, place your large grain bag into the kettle and secure it to the edge of the pot with the binder clips.

Step 3: Add Grains

Slowly pour your grains into the bag. If you can, stir as you pour to keep the grains from clumping. If a helper is available, then one person can pour while the other stirs. Once all the grains are in, give it a good stir to be sure there are no clumps.

Step 4: Mash For 90 Minutes

Check the temperature and cover the kettle. Per our recipe, we should be mashing at 152 °F (67 °C). Add a little

A good kettle is the foundation for success with brew-in-a-bag. A good rule of thumb is to have a kettle that is at least twice the batch size intended for the fermenter.

> “Whenever you remove the lid, give your mash a good stir. This will help to evenly distribute the heat and help with the conversion process.”

heat, if needed, to get to the mash temperature. Once there, cut the heat and either place some folded blankets on top of the kettle, or put an old winter coat around it for added insulation. Be sure to remove any insulators before turning on your burner.

The recipe calls for a 60-minute mash, but always mash for 90 minutes when using BIAB to increase efficiency, being sure to set your timer. You are now officially brewing all-grain!

Step 5: Check Temperature and Stir

Periodically check your temperature to be sure you're maintaining the mash temperature as consistently as you can. This is where it's nice to have a thermometer on the outside of the kettle so you don't have to keep removing the lid and losing heat while checking temps.

Whenever you remove the lid, give your mash a good stir. This will help to evenly distribute the heat and help with the conversion process. It will take practice to know how much heat to add and when to cut it.

Step 6: Mashout

Remove any blankets or other insulators and raise the temperature to 170 °F (77 °C). Once you reach temperature cut the heat and give the mash a good stir, then cover for 10 minutes. We are performing this step to help increase our efficiency.

Step 7: Remove The Grain Bag

Remove the cover and give the mash one last stir, then remove the binder clips. Slowly lift the bag out of the wort, allowing the wort to drain from the bag. It's going to be hot, so wear some rubber gloves to help protect your hands. After most of the bag has drained, you can set the bag on a large colander and place it over a bucket to allow it to drain further. Once it's drained off, simply add it to the boil. Also, be sure to fish-out the colander you may have used as a false bottom before you start the boil.

If your kettle happens to have a steam basket then you can lift the steam basket with the bag out of the kettle and set it on top (partially on its side) of the brew kettle so it's supported by the rim of the kettle itself. Then you can let the bag drain directly into the kettle.

Once you have finished that process, you can properly dispose of your spent grains, record your pre-boil volume, and collect your pre-boil gravity sample. Next, prepare for your boil by following the recipe as you normally would. Be sure to rinse your bag clean and hang it to dry for next time! BYO

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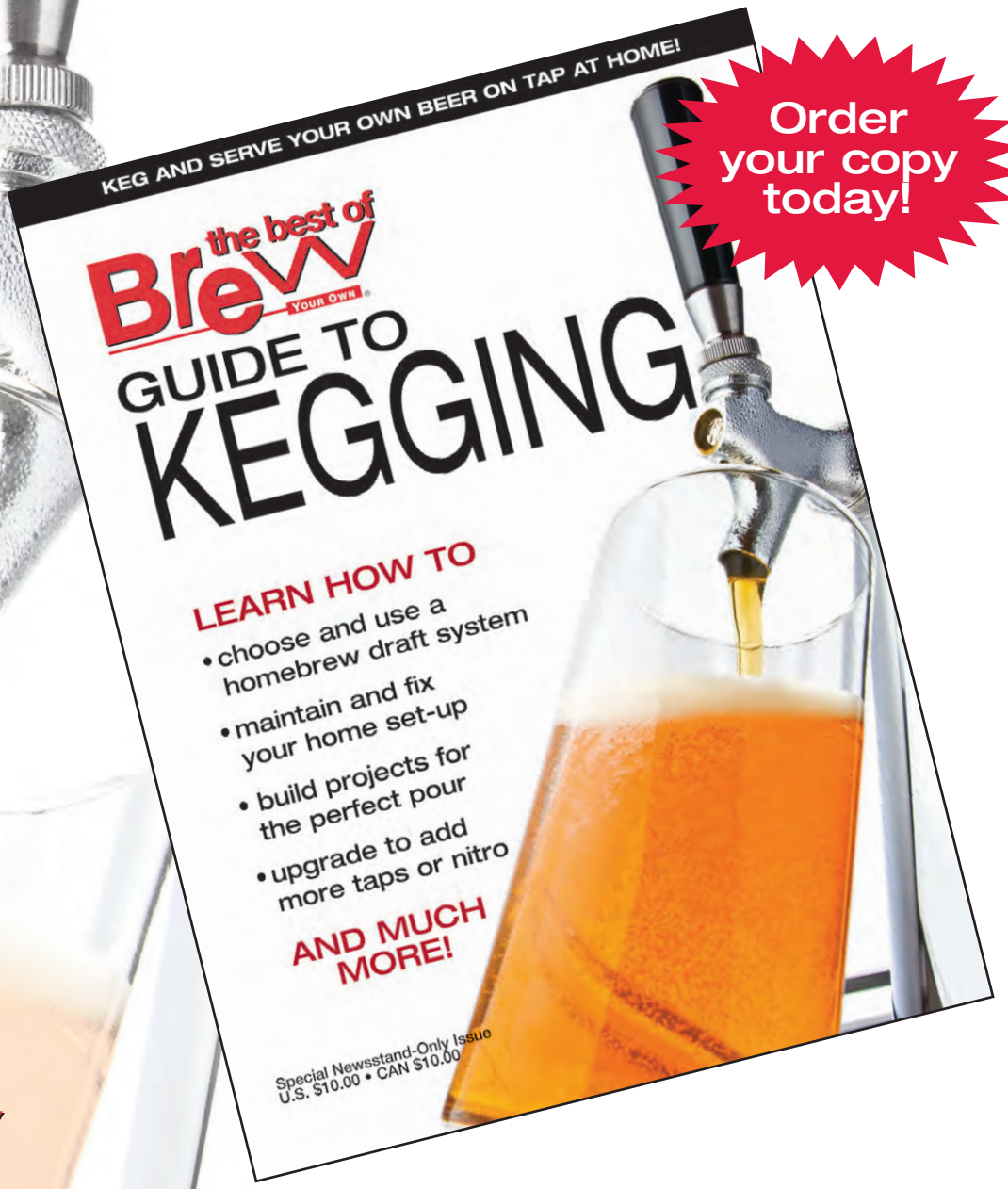

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BREWING WATER & pH

As you start to get more serious about all-grain brewing, you should start paying attention to your brewing water chemistry and the pH of your mash. Controlling the pH of your mash can make the difference between an average beer and something special. In this section, we will discuss the importance of understanding and measuring pH in your mash and how the chemistry of your brewing water affects your homebrews.

Photo by Charles A. Parker/Images Plus

Understanding pH

How to create a happy medium in your mash

by **Nico Freccia**

The level of pH in your mash, wort, and beer affects processes from enzyme function to hop extraction to yeast vitality. Understanding pH helps you manipulate pH levels for great-tasting beer.

But while pH is important, trying to understanding it can be a confusing affair. Your homebrew shop carries pH test strips and probably more expensive and elaborate pH meters. People talk about the pH of water, the mash, and the wort. But what is pH, what is important about it, and what do you really need to know about pH as a homebrewer?

What It Is

The term pH expresses the degree of acidity or alkalinity of a solution, in which "p" is the negative logarithm of "H," hydrogen concentration (pH = -log[H+]). The level of pH is measured on a scale of 1 to 14, 7 being neutral, below 7 acid, and above 7 alkaline (also called basic). Because the scale uses the exponent of 10 in the logarithmic scale, a solution of pH 5, for example, will be 10 times more acidic than a solution of pH 6 and 100 times more acidic than a pH 7 solution.

Technical definitions aside, what does pH mean, in a practical sense, to the homebrewer? The pH of the mash affects the activity of enzymes and is critical for the amylases (a family enzymes) responsible for saccharification (conversion of malt starch into fermentable sugars, particularly maltose) and liquification. Different enzymes required in the mash function at different optimum pH levels, but a happy medium is achieved between pH 5.2 and 5.5. This means healthy yeast, which also perform well at a pH of about 5.5. As the yeast ferment the wort, pH drops and creates a more and more inhospitable environment for bacteria. Achieving the proper mash pH will also significantly affect hop extraction rate in the boil, facilitate proper protein precipitation, clarification of the wort, and color pick-up, and ultimately affect the flavor of the beer.

How pH Functions in Brewing

Before manipulating pH to achieve optimum levels in the mash and wort, it is wise to review some basic principles of chemistry and biology. A fundamental quality of biological systems is their ability to maintain homeostasis (stay the same). Though systems constantly exchange materials with their surroundings, they will maintain a relatively stable internal environment. The maintenance of a stable pH and resistance to sudden changes in pH is an example of this quality. Where pH is concerned, systems maintain this stability through the use of "buffers." For example because of buffering in the human body, we are able to drink beer, which has a

> "Being familiar with the mineral content of your water can help you achieve the proper pH in your mash."

Photo by Charles A. Parker/Images Plus

The pH of your mash can be influenced by the chemistry of your brewing water.

Measuring pH

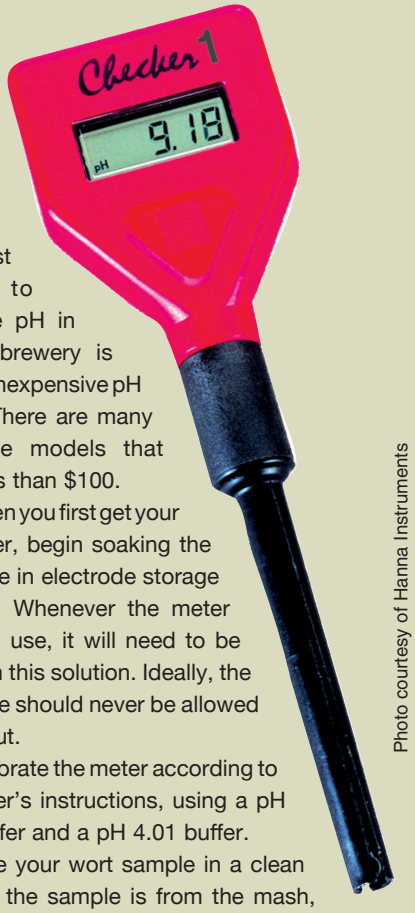

Photo courtesy of Hanna Instruments

The best way to measure pH in a homebrewery is with an inexpensive pH meter. There are many adequate models that cost less than $100.

When you first get your pH meter, begin soaking the electrode in electrode storage solution. Whenever the meter is not in use, it will need to be stored in this solution. Ideally, the electrode should never be allowed to dry out.

Calibrate the meter according to the meter's instructions, using a pH 7.01 buffer and a pH 4.01 buffer.

Take your wort sample in a clean glass. If the sample is from the mash, cool it down to room temperature, even if your pH meter has automatic temperature control. Taking readings of hot samples will decrease the life of the electrode. Rinse the electrode with distilled water then dry the electrode with a tissue. Don't let the tissue touch the electrode, just bring it close enough to wick the liquid away.

Place the electrode in the sample and give the sample a quick swirl. Make sure there are no bubbles attached to the electrode. Turn on the power to the electrode. The power to the electrode should never be on unless the electrode is submerged.

With the power on the electrode, the meter will take the reading. Note it in your lab notebook, then turn the power to the electrode off before pulling it out of solution. Rinse the electrode with distilled water again, dry and return to the storage solution.

Since pH changes with temperature, you need to compensate for this change. At room temperature, the pH of the cooled sample will be around 0.35 units higher than the pH at mash temperature. Thus, if you get a reading of pH 5.60 for your cooled sample, your corrected reading would be pH 5.25. (You need to do this even if your meter has temperature correction.)

~ Chris Colby

pH of 4 to 4.5, while our blood maintains an extremely constant pH of about 7.4.

In a solution of pure water (H_2O) at neutral pH 7, some water molecules will ionize, or dissociate, into H+ ions and OH- ions. Because the water is pure, there will always be the same number of H+ and OH- ions. However, when a compound that contains H+ ions is introduced into the water, the H+ ion concentration will increase. The greater concentration of H+ ions causes the water to become more acidic, and so the pH drops. Buffers maintain a constant pH because they combine with H+ ions and either remove them from solution (as in this example) or add them back, essentially "soaking up" the acid or base. If enough acid or base is added, it will eventually overcome the buffer and the pH will rise or fall accordingly.

Malted barley contains phosphates, which are acidic buffers. Making a mash of grain mixed with water will cause the phosphate buffers to achieve a natural pH of around 5.6. Therefore, it does not matter what the initial pH of your brewing water is because the interaction between ions in water and buffering components of the malt will always change the water pH. Remember that the optimum mash pH range is between 5.2 and 5.5, so the pH of the mash needs to come down a bit to ensure complete conversion, good hop utilization, and other desirable characteristics. This is where the brewing water comes in. While the pH of the brewing water may be inconsequential, its ion concentration is of the utmost importance.

pH and Brewing Water

Being familiar with the mineral content of your water can help you achieve the proper pH in your mash. All municipal water suppliers publish a water quality or water analysis report that they will send you upon request. If you brew with well or bottled water, you should have the water tested or contact your water supplier for an analysis (read more about interpreting a water report in the sidebar on page 45). If your water supply comes from a source that has varying levels or is subject to fluctuations due to rainfall, ion concentrations may vary greatly at different times of the year.

The important ions that will affect mash pH are calcium, magnesium, and the carbonate and bicarbonate ions. These ions should be listed on your water report in either parts per million (ppm) or milligrams per liter (mg/L) — they are equal measurements. Calcium is the key ion able to overcome the buffering capacity of the malt phosphates and lower the mash pH into the acceptable 5.2 to 5.5 range. Ideal concentrations of calcium should be between 50 and 150 ppm. Magnesium acts much the same as calcium, but it is less effective at reducing mash pH. Ideal calcium concentrations, however, must be balanced with low carbonate-bicarbonate levels. Carbonate and bicarbonate ions will have a countering effect on calcium. Bicarbonates in particular are strong alkaline buffers and in large amounts will raise the pH of the mash to unacceptable levels. Carbonate and bicarbonate ions should be kept to less than 50 ppm.

The carbonate and bicarbonate ions will often be lumped together on a water report and termed "CO_3." They may not be listed separately, but they might be included under the headings for alkalinity and hardness and termed "$CaCO_3$," which describes alkalinity and hardness as the combined presence of calcium and the carbonate and bicarbonate ions. When you get the report you should compare the two numbers for alkalinity and hardness. If the alkalinity rating is greater than the hardness rating, you may need to remove carbonate ions from your brewing water to avoid raising the pH of the mash. If the hardness rating of the water is greater than the alkalinity rating, the ratio of calcium to the carbonate ions is probably well suited to brewing. If the two numbers are equal or are both low (less than 50 ppm) you will probably only need to add some calcium from calcium sulphate or calcium chloride back to the water to make it satisfactory for brewing.

Manipulating pH in the Homebrewery

As we have seen, ion concentration in brewing water will have a great effect on the mash pH. Type of malt is another important contributing factor. Dark malts, for instance, are naturally acidic and will overcome the buffering power of carbonate waters, dropping the pH into the correct range. For the time being let's assume we're brewing only pale beers.

Remember that changes to the pH of the mash, wort, or beer will be due to the addition or removal of mineral ions or the addition of organic acids. Adding mineral salts is the most common way to adjust mash pH. Mineral salts, such as gypsum, are compounds formed by a positively charged ion and a negatively charged ion. Gypsum combines the calcium ion with the sulfate ion and is an excellent source of calcium to aid in acidifying the mash. Adding one teaspoon of gypsum to 5 gallons (19 L) of water will raise the calcium level by about 60 ppm. If your brewing water is very soft (low in total minerals), you can add gypsum to raise calcium levels. If your water is high in carbonates, boiling the water for 30 minutes with calcium (either present in the water or added in the form of gypsum) will cause the calcium and carbonates to combine and precipitate out, forming a white residue in your kettle. Decant the water off the residue, leaving the carbonates (and calcium) behind. Because you've just removed much of the beneficial calcium as well as the detrimental carbonates, you may need to add gypsum to the water to raise calcium levels again before mashing.

If you want to brew a classic Pilsner using pale malts and soft water, you may want to employ an acid rest to ensure the pH drops to the correct range. During an acid rest, the enzyme phytase breaks phytin, a phosphate containing both calcium and magnesium that is found in the grain, down into phytic acid. In other words, phytase helps lower the mash's pH. This is particularly important for water that has too little calcium to lower pH, such as the water of Plzen, the original home of Pilsner.

> "The important ions that will affect mash pH are calcium, magnesium, and the carbonate and bicarbonate ions."

The enzyme works best at temperatures between 86 and 128 °F (30 and 53 °C).

The acid rest will acidify the mash to the proper range and will also provide minerals and nutrients for the yeast. An acid rest will be unnecessary for beers made using any highly kilned malts such as crystal and dark malts and even British pale malts, because these malts will be acidic enough on their own to lower the mash pH.

The other alternative to acidifying the mash is to add lactic acid. Lactic acid blends very well with beer and will not add any unwanted flavors. You should be able to find it in your favorite homebrew shop along with instructions for use.

Again, dark malts are naturally acidic and will lower the mash pH. Even crystal malts will have some acidic effects, and the simplest solution to poor brewing water is to use a proportion of dark malts. Many great brewing centers of the world, particularly London, Dublin, and Munich, have water low in calcium and high in carbonates. The alkalinity of the water makes brewing pale ales or lagers difficult without acidification of the mash. But because they traditionally brew darker beers, such as porters, the acidity of the malt is able to overcome the buffering of the carbonate water.

pH and Sparge Water

The pH of the sparge runoff should be below pH 6. Higher pH couples with too high sparge water temperatures to extract tannins, silicates, and other undesirable compounds from the grain, which create astringent off- flavors and cloudy, hazy beer. Too high pH should not be a problem because the sparge water will mix with the mash and its pH will naturally be lowered. However, if your water supply is highly alkaline and you treated it by boiling to precipitate out calcium and carbonates for the mash, you should do the same to the sparge water. Using untreated, highly carbonate sparge water may raise the pH of the runoff above acceptable levels.

Unless you are brewing very specialized beers using undermodified malts, very pale malts, or soft water, you shouldn't worry too much about pH. You may need to make some adjustments such as boiling or adding gypsum, but for the most part the wort will take care of itself. Expensive pH meters will give you very accurate pH readings but are probably only necessary if you are aiming for very specific results. BYO

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WATER treatments

Better beer through chemistry

by **Jon Stika**

Water is the main ingredient of beer. The many different styles of beer we have today evolved for many different reasons, not the least of which is the chemistry of the local water supply where the beer was created. Historically, brewers no doubt experimented with different ingredients and techniques much as homebrewers do today. They undoubtedly settled on recipes that worked best for what they had readily available . . . including water. Without having a comprehensive knowledge of what was dissolved in their brewing water and its effect on mash pH, expression of hop bitterness, etc. the brewers nevertheless found their way and the rest, as they say, is history.

What's In the Water?

With the information and technology we have today, we can discern what ions are present in solution in our water and the water of famous brewing regions of the world. If you live in the US and use municipal water, your local water board should send you a summary of what is in your water every year. If you don't receive this publication, you can request it. Alternately, if you have a private water supply (well, spring, etc.), you should have it analyzed by a private or state-run lab that does such work.

Results shown on water analysis reports are typically expressed in milligrams per liter (mg/L) or parts per million (ppm). In the range of concentrations we are concerned with, you can use these interchangeably. Once you have an analysis of your brewing water, you can compare it to the analysis of the water from brewing centers from around the world and see which beer style fits your local water best. Before we dive into that, though, here's a quick refresher on the basics of water chemistry.

Water is a molecule composed of a central oxygen atom with two smaller hydrogen atoms attached. A space-filling model of water looks a bit like Mickey Mouse, with the oxygen being his head and the two hydrogens his ears.

Many different types of minerals dissolve in water. When they do, some dissociate (break apart) into their component ions. For example, sodium chloride (NaCl) dissolved in water would dissociate into two ions, Na^+ and Cl^-. An ion is simply an atom or molecule that has a different number of electrons than protons. This difference results in either a net positive charge (cation) or a net negative charge (anion). These ions float around in solution in water and are available to react with other ions and affect everything from mash pH to the flocculation of yeast.

What if your water is best suited for a Pilsner and you want to brew an Irish

> "Various salts may be added to adjust your water chemistry to suit a particular style of beer."

Photo by Charles A. Parker/Images Plus

A basic understanding of the chemistry of your brewing water can help you brew better beer.

> “Two things all brewing waters require is that they taste good and they be free of chlorine compounds.”

DESIRED ION CONCENTRATIONS IN BREWING WATER

Chemical	Formula	Desired Range mg/L (ppm)	
		Minimum	Maximum
Calcium	Ca^{2+}	50	150
Magnesium	Mg^{2+}	10	30
Sodium	Na^{+}	0	150
Carbonate Bicarbonate	CO_3^{2-} HCO_3^{-}	0	250
Sulfate	SO_4^{2-}	50	350
Chloride	Cl^{-}	0	250

stout? Various salts may be added to adjust your water chemistry to suit a particular style of beer. But first let’s look at some important ions in brewing water, how they affect beer flavor, and how their concentrations relative to each other can create flavor synergies.

Basic Brewing Chemistry

Pure water — for example, distilled water or water purified by reverse osmosis (RO) — without any mineral ions in solution, is not used by commercial brewers. It is the dissolved ions in water that are important for mash chemistry, expression of various flavors (sweet, sour, salty and bitter in particular) and yeast nutrition. Therefore it is not a good idea to brew all-grain beer with distilled or reverse osmosis water. (See the table at the top of this page for some general guidelines of desired concentrations of each important ion in brewing water).

Water with high levels of minerals dissolved in it, especially calcium and magnesium, is called hard water. Water with few dissolved minerals is called soft water. For brewers, it is more important to know the concentrations of key minerals that are dissolved in the brewing liquor than whether their water is hard or soft.

Water with very low levels of carbonates (i.e. Pilsen, Czech Republic) will allow mash pH to come into proper range (5.2–5.6) with only pale malt (especially if a little calcium is present). If the carbonate levels are higher, more acidic malt is necessary to properly lower the pH. For example, hard water dominated by carbonates like Dublin, Ireland, with its high level of carbonates, is well suited to brewing stouts. Carbonates and bicarbonates can be precipitated as calcium carbonate ($CaCO_3$) by boiling water in an open kettle for at least 15 minutes where it can pick up oxygen to react with and drop out of solution. This process will typically reduce carbonates and/or bicarbonates below 150 ppm. Carbonates can also be reduced by neutralizing them with acid. Food-grade phosphoric acid is a popular choice for this in breweries.

Calcium ions (Ca^{2+}) in water react with phosphates in malt, releasing acid. Thus, its presence in mash water lowers the pH of the mash. Calcium is not a significant yeast nutrient, but does facilitate yeast flocculation and subsequent precipitation. Calcium also stabilizes alpha amylase and increases its tolerance to the heat of mashing.

Magnesium (Mg^{2+}) is important for enzyme activity in the mash and for yeast nutrition. Like calcium, magnesium ions drive down the pH of a mash, but to a much lesser extent than calcium. Magnesium enhances beer flavor up to a point, then lends a dry, bitter metallic flavor to beer.

Sodium (Na^{+}) has different effects at different concentrations. At low levels, sodium contributes sweetness, probably by balancing bitterness, and adds some palate fullness, which may be appropriate in certain styles of beer. At higher levels, sodium can contribute to salty flavor.

Sulfate (SO_4^{2-}) has a very high solubility in water and waters high in sulfate are known as “gypseous” waters. Sulfate ions bring out the hop character in a beer.

Chloride ions (Cl^{-}) give a full, sweet flavor to beer, but they are not a significant player in mash chemistry or yeast nutrition. Many brewers use calcium chloride instead of calcium sulfate because chloride has a flavor affect that many brewers like.

Chlorine (Cl_2) is often included in municipal water supplies as hypochlorous acid (HOCl) or chloramine (NH_2Cl) to serve as a disinfectant. If either of these compounds remains in brewing water they can lend a harsh, medicinal flavor to beer.

Hypochlorous acid can be removed by boiling brewing water in an open pot for at least 15 minutes prior to using the water in the mash or

boil. Remove chloramines from water by adding a crushed Campden tablet to 20 gallons (76 L) of brewing water and letting the water sit uncovered overnight to allow the resulting chlorine gas to dissipate.

Of course, the simplest way to lower an ion in your water is to substitute a portion of your tap water with distilled or reverse osmosis (RO) water that is essentially free of mineral ions. For example; to reduce the concentration of the ions in your tap water by half, use half tap water and half distilled or RO water to make up the total volume of water for the batch of homebrew.

The Short Course on Water Treatment

The details of water chemistry can be complex and many brewers may simply wish to know if they can use their water as is, or learn a simple treatment plan to deal with their water.

Two things all brewing waters require is that they taste good and they be free of chlorine compounds. (See the section earlier for how to treat for these chlorine compounds.)

If you are an extract brewer, the requirements your water must meet are broader than if you are an all-grain brewer. This is because you do not have to worry about mashing your grains. This has been done for you at the malt extract plant. Malt extract is condensed wort, and all (or most) of the dissolved solids present when the grains were mashed are contained in the extract, including mineral ions. When brewing with malt extract, you simply reconstitute your wort from this concentrate. If you use distilled water, or very soft tap water, your reconstituted wort should contain all the minerals required for brewing. If your water is hard, you will be adding minerals to your wort beyond what is required. In small amounts this will likely have no discernible effect. If your water is very hard, especially if it is rich in carbonates, you may want to consider blending it with distilled or RO water to make your brewing water. You do not need to add salts to your brewing water to try to emulate the water of different brewing cities (such as Burton). Unless you know the minerals that are already in your malt extract, you are blindly piling on more minerals. For hoppy beers, you may wish to accentuate the hop profile by adding a little gypsum. Likewise, for malty beers, a little calcium chloride may make for a smoother beer. In either case, don't overdo the addition. Use a maximum of 2 teaspoons per 5 gallons (19 L) of these salts.

Photo courtesy of Wikipedia

Dortmund, Germany is known for pale lagers. The water in Dortmund has higher levels of minerals yielding a more assertive malt character in the city's beers.

All-grain brewing additionally requires that the water chemistry yields a suitable mash pH. A simplified version of how to obtain this can be had by remembering a few key things. Calcium ions (and to a lesser extent, magnesium ions), dark malts and acids will lower mash pH. Carbonates neutralize acids and decrease the amount that mash pH is lowered by these things.

Calcium has other beneficial actions in brewing, such as stabilizing alpha amylase in the mash. Thus, unless stylistically required to have less, it's best to have at least 50 ppm calcium in your wort. For pale beers, the amount of carbonates should be minimized, at least under 50 ppm. For dark beers, carbonate can be a good thing and for stouts, your water may require up to 250 ppm carbonates.

Manipulating just the calcium and carbonate levels is the simplest way for an all-grain brewer to treat their water. To reduce carbonates, if needed, you can blend your tap water with distilled or RO water, or add acid. If you need to increase it, you can add calcium carbonate (chalk) or sodium bicarbonate (baking soda).

Once your carbonate levels are

WATER PROFILES OF FAMOUS BREWING REGIONS (mg/L or ppm)

City	Calcium	Carbonate or Bicarbonate	Sodium	Sulfate	Magnesium	Chloride
Burton on Trent, UK	295	300	55	725	45	25
Dortmund, Germany	250	550	70	280	25	100
Dublin, Ireland	115	200	12	55	4	19
Edinburgh, Scotland	120	225	55	140	25	20
London, England	52	156	99	77	16	60
Pilsen, Czech Republic	7	15	2	5	2	5

CONCENTRATION OF SALTS IN BREWING WATER (1 Gal./3.7 L)

Salt			Concentration from one level teaspoon in 1 gallon (3.7 L) of distilled water (mg/L or ppm)					
			Calcuim	Carbonate or Bicarbonate	Sodium	Sulfate	Magnesium	Chloride
Common Name	Chemical Name	Chemical Formula	Ca^{2+}	CO_3^{2-} HCO_3^-	Na^+	SO_4^{2-}	Mg^{2+}	Cl^-
Baking Soda	Sodium Bicarbonate	$NaHCO_3$	-	842	330	-	-	-
Calcium Chloride	Calcium Chloride	$CaCl_2$	245	-	-	-	-	432
Chalk	Calcium Carbonate	$CaCO_3$	189	284	-	-	-	-
Epsom Salt	Magnesium Sulfate	$MgSO_4$	-	-	-	464	117	-
Gypsum	Calcium Sulfate	$CaSO_4$	246	-	-	590	-	-
Canning Salt	Sodium Chloride	NaCl	-	-	633	-	-	1733

CONCENTRATION OF SALTS IN BREWING WATER (5 Gal./19 L)

Salt			Concentration from one level teaspoon in 5 gallons (19 L) of distilled water (mg/L or ppm)					
			Calcuim	Carbonate or Bicarbonate	Sodium	Sulfate	Magnesium	Chloride
Common Name	Chemical Name	Chemical Formula	Ca^{2+}	CO_3^{2-} HCO_3^-	Na^+	SO_4^{2-}	Mg^{2+}	Cl^-
Baking Soda	Sodium Bicarbonate	$NaHCO_3$	-	168	66	-	-	-
Calcium Chloride	Calcium Chloride	$CaCl_2$	49	-	-	-	-	86
Chalk	Calcium Carbonate	$CaCO_3$	38	57	-	-	-	-
Epsom Salt	Magnesium Sulfate	$MgSO_4$	-	-	-	93	23	-
Gypsum	Calcium Sulfate	$CaSO_4$	49	-	-	118	-	-
Canning Salt	Sodium Chloride	NaCl	-	-	126.6	-	-	347

adjusted, you can add calcium — if needed — as either calcium sulfate (usually in the form of gypsum) or calcium chloride ($CaCl_2$). Simple water chemistry calculators are available online that will do all the math for you. These include Greg Noonan's "Water Witch," available for download at http://byo.com/resources/brewwater.

Whether an all-grain or extract brewer, always taste your brewing water after you have treated it, and don't proceed if you detect off flavors or aromas. If you do taste something off, double check that you used the correct mineral salts. Don't taste your water for several hours after adding Campden tablets.

Creating Chemistry

Another approach to dealing with brewing water chemistry is to start from scratch with distilled or reverse osmosis (RO) water and add salts to make the water what you wish it to be. This method may be preferred if you are attempting to brew a beer with a water profile at an extreme end of the brewing spectrum. For example, say you wanted to reproduce the water profile of Dublin, Ireland in order to brew a traditional Irish stout. How could this be done at your homebrewery? Beginning with distilled or RO water, you would need to add some of the major brewing ions (Ca^{2+}, HCO_3^-, Na^+, SO_4^{2-}, Mg^{2+}, Cl^-) to approximate the water profile of Dublin. Charts detailing specific information about the brewing water of famous brewing regions are readily available online or in most brewing texts.

Adjusting or creating a brewing water profile to suit the production of a particular style of beer does not require a degree in chemistry, just a solid understanding of what you need. If you get a handle on the concentrations of the major brewing ions in your water, and compare it to your target water, you can approach your homebrewing water treatment one of two ways — either by altering your tap water to approximate your target water or by starting from scratch with distilled or RO water and adding some commonly available salts. BYO

Reading a Water Report

Brewing water can be confusing, especially to a new homebrewer who is starting to brew all-grain batches. All you need to know in the beginning, however, is if six certain ions in your water are in the proper range, which you can easily find out from reading a water report.

If you live in a place that has municipal water, you can request a water report from your department of public works. If you are using spring, well, or some other source of tap water you won't have a public water report, but you can have it similarly tested by a private lab for its content.

Water reports intended for the general public are typically expressed in parts per million (ppm), which is defined as one milligram of the substance per liter (1 mg/L).

The ions

The six important ions in water that you need to know about for brewing are: calcium, magnesium, bicarbonate (or total alkalinity as $CaCO_3$), sodium, chloride, and sulfate.

• Calcium should be in the range of 50–150 parts per million (ppm). Calcium is an ion that makes water "hard," and it is important for many yeast, enzyme and protein reactions. Hardness is a measure of the calcium and magnesium content in water. When there is an equal amount of calcium and bicarbonate present, it is known as "temporary hardness," which can be reduced by boiling. Permanent hardness is measured by the amount of calcium that can't be removed by boiling. Water hardness is either good or bad, depending on what style of beer you want to brew. For example, temporary hardness is good for dark beers and permanent hardness is good for brewing pale ales. Research the style of beer that you want to homebrew to figure out if the hardness of your brewing water is appropriate for what you want to brew.

• Magnesium should be in the range of 0–30 ppm. It also contributes to water hardness and is a yeast nutrient. Magnesium is best kept at small amounts because it can contribute off/bitter/metallic flavors to the beer. Magnesium can also give food and beverages a laxative effect, which is another reason to limit this ion in brewing water.

• Bicarbonate should be 0–250 ppm - or if your report reads as "total alkalinity" it should be in the 0–200 ppm range. More specifically (according to John Palmer's How To Brew), bicarbonate should be 0–50 ppm for pale, base-malt only beers. 50–150 ppm for amber colored, toasted malt beers and 150–250 ppm for dark, roasted malt beers (these levels assume calcium in the range of 50–100 ppm to balance the alkalinity of the bicarbonate). Bicarbonate affects the pH of your water. A high pH in the mash can cause poor extraction rates, darken the wort, and leach more tannins into your mash. (For more information about pH in brewing, visit http://byo.com/story1495)

• Sodium should be between 0 and 150 ppm. Sodium in moderate levels can accentuate malt flavor.

• Chloride can be anywhere between 0 and 250 ppm. Chloride is similar to sodium in that it can accentuate malt flavor if it is in a moderate range. If there is too much chloride, however, the beer can suffer from off flavors.

• Sulfate should be around 0 to 150 ppm. Sulfate can accentuate hop bitterness in moderation, but too much can make the bitterness seem harsh.

~ Betsy Parks

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LAUTERING

Once you've extracted the malt sugars you need for your beer from your grains during mashing, it's time to rinse the grains and separate the wort from the mash in order to move on to the next stage of brewing. Following proper lautering practices will ensure that you will achieve a high extract efficiency while avoiding astringent flavors and filtering out much of the small solids in the wort. In this section, we will explore the basics of lautering as well as the three most popular styles of sparging: fly, batch, and "no sparge."

Photo by Charles A. Parker/Images Plus

A Guide to LAUTERING

Recirculate and rinse your grains

by **Randy Whisler**

Considering how important it is to the brewing process, lautering (also known as sparging) doesn't get much respect. Many brewers see it as simply the process of rinsing grains. They give it little thought, rush through it, and curse it if problems arise such as a stuck lauter.

But a successful lauter plays an important role in getting the most from your grains, avoiding astringent flavors, and making your brewing more consistent. Lautering, by definition, is simply the separation of liquid wort from mash solids. The process of lautering gives the brewer the wort needed for making beer. Lautering begins after the mash. Mashing converts starch into fermentable and unfermentable sugars, also known as dextrins, produces some amino acids from proteins and in general produces what brewers call "extract" from malt. Much of what is contained in extract is used by yeast to convert wort to beer. The mash solids, the portion of the malt that is not converted to extract in mashing, is unwanted by the brewer and needs to be separated from wort. This fact was empirically realized by early brewers and led to the development of what we now call the lauter process.

The basic principles of lautering involve putting the mashed grain into a vessel with a sieved bottom. Using the most standard setup, you will mash and lauter in the same (sieved-bottom) vessel. The sieve can be anything from a leg out of a pair of nylons (usually large and preferably never before worn) to a V-plate stainless steel false bottom installed in one of those large, round water coolers. The sieved vessel then allows the liquids of the mash to flow out of the mash tun into another vessel.

However, there is a small problem here. This wort that first flows from the lauter vessel has a very high initial gravity, which is not always preferred by the brewer, and a brewer who just drained the lauter without adding more water would lose a large proportion of extract that would otherwise be converted to beer by yeast

> "Lautering, by definition, is simply the separation of liquid wort from mash solids."

Photos by Charles A. Parker/Images Plus

To extract all of the malt sugars from the grain bed as possible, all-grain brewers must rinse the grains over a period of time, which is known as "sparging." Above a brewer is fly sparging.

Fly Sparging

Continuous or "fly" sparging means sprinkling hot water over the grain and allowing it to trickle through the bed. This involves balancing the rate of sparging with the rate of wort run-off so that there is always an inch or so of water on top of the bed. Higher water levels will increase the pressure drop across the bed, which could pack the grains down tightly and slow the process considerably. If the bed dries out at all, it will crack open channels and the sparge water can run right through the bed without picking up any of the retained wort.

Therefore, sparging takes some attention on the part of the brewer, and some extra equipment. The most common method of continuous sparging is to use a sparge arm, which you can either make yourself or buy from a supplier for $20-$40 depending upon the model. A sparge arm consists of a piece of tubing with a second tube at right angles to it; perforations on the latter mean that it swivels about the former when hot water passes through it. The upper tube is connected to the hot liquor tank; the valve on that is opened as you start run-off and the hot water is sprinkled gently over the bed by the rotating perforated arm (see photos of a sparge arm in action on pages 46 and 47).

Generally you would use an amount of sparge water that will top up to the volume of the finished beer (5 gallons/19 L in an average example). It should be at a temperature of around 170 °F (77 °C), since this will keep the bed at a reasonable temperature and the wort at a low viscosity so that the water will flow freely through the bed. Sparging in this way is quite an efficient process, as all the water has to pass from top to bottom of the bed allowing good contact between water and grain. The more slowly sparging is carried out, the better that contact will be, and many believe one to two hours duration to be optimal, though that does depend upon how finely the grain has been ground. For many of you that extra time on your brew day may be unacceptable, and many brewers only sparge for about 30 minutes.

There are some other points about continuous sparging to consider. The first being that the sparge water should ideally be treated (that is with whatever added salts) the same way as you would treat the mash water. If it is not, then as the sparge continues, the pH of the liquid in the tun may rapidly increase as the gravity drops and unwanted materials such as silica and tannins may be leached out into the wort. Even with treated sparge water, the wort pH will increase as the gravity drops so care and control are needed. Therefore, it is normal practice to stop sparging when the liquid from the tun has reached a specific gravity (SG) of about 1.008–1.010 (2.1–2.6 °P). By that time you should have collected 5.5-6 gallons (21–23 L) of wort, and be ready for the boil.

during fermentation. So unless you want really small batches of high-alcohol beer, and/or a very inefficient use of valuable raw materials, you have to add more water back into the lauter.

The Process

The details of the lautering process depend to some extent on the equipment you use and the type of beer you are brewing. For this example we'll look at a beer of medium starting gravity, lautered in the most standard of homebrew mash/lauter tuns, a 5-gallon (19-L) bucket with many, many holes drilled into the bottom of it, stacked into another five-gallon bucket with a spigot near the bottom.

At the point when you are just completing your mash and are ready to lauter, the mash water will serve as foundation water. Foundation water allows the mash to float rather than become wedged into the sieve. If you were lautering in a separate vessel, you would fill the bottom with 175 °F (79 °C) water and add the mash.

Hot water is preferred to cold water for lautering. Hot water extracts more sugar than cold water. There are many chemical/physical principles at work here, but they can all be boiled down into a maple-syrup example. If you have ever tried to pour maple syrup straight from the refrigerator onto your waffles, you know the syrup does not pour very fast. But if it is heated, it pours much more quickly.

The same is true for the sugars in the mash. If you add cold water to them, they will move very slowly through the lauter. But if you add hot water, the sugar molecules move around much faster and are therefore extracted much faster. Another reason for using hot water is that you will be able to bring the wort to a boil faster once lautering is completed.

Once the mash is complete, let it settle for about five minutes. This allows the grain bed to sort of settle out. At the end of the five minutes, open the spigot and start running off slowly. The lautering process should take about an hour; it's not a race. A common mistake made in lautering is

to zip the water through the lauter and into the boil as fast as possible.

At the start of the lautering process, you should use a quart container or similar vessel to catch the first runnings (see photo at top right). These will be cloudy and have bits of husk in them. Pour the cloudy, husky material back into the top of the lauter. This process is called vorlauf, a German word that means "forerun". The mash materials will act like a filter and clear the runnings (see photo at right bottom).

Repeat this process until you are satisfied with the clarity of your wort. Some worts never become totally clear, while others can become almost crystal clear. It depends on your lauter tun design and the type of malt and adjuncts you are using. However, as a general rule you should at least vorlauf long enough to get the husky material out of the runoff. Fifteen minutes is a reasonable time for the vorlauf.

Once you have reached the desired clarity, you can start running off into the brew kettle. Again, this is not a race. You should take at least 45 minutes to run the rest of the water through the lauter vessel. You will notice that the water level in the lauter tun will begin to get low as you drain off the bottom liquid.

At this point you should be adding hot water back into the top of the lauter. One of the simplest methods is to put boiling or near-boiling water into your quart vorlauf container (pitchers work well for this purpose as shown in the photos at right) and add the sparge water as needed to the lauter vessel. It is a good idea to keep the water level in the lauter about an inch above the grain bed.

This is one simple method for adding sparge water to the lauter tun. There are many tools available to help the brewer add water evenly over the top of the lauter bed. Some are as complicated as another bucket attached to a tube that runs into a second, T-shaped tube. When water is added to the bucket, the T-tube spins around like a lawn sprinkler (see the photos on page 46 and 47). This is called continuous sparging or "fly" sparging (see sidebar on page 48).

Photos by Charles A. Parker/Images Plus

Photo by Les Jorgensen

One of the first steps in lautering is to "vorlauf" or recirculate. This is done by collecting the first runnings and pouring them back over the grain bed. If you crushed properly, the bed will act as a filter to remove much of the husky material in first wort runnings.

Photo by Charles A. Parker/Images Plus

The first runnings, which is the very first wort that comes out of the lauter tun when you begin to drain the mash, has a very high initial gravity and is also often very cloudy and cluttered with small bits of grain husk that have accumulated at the bottom of the vessel. Recirculate to clarify the wort before transferring it to the kettle for boiling.

The important thing is to evenly distribute the water over the top of the lauter. This allows the water to flow evenly through the grain bed. The whole purpose of adding the extra water is to extract more sugar. Therefore, it makes sense to evenly distribute the water. If the water does not get to a certain spot in the lauter bed, you will get what are called sweet spots. Sweet spots represent lost extract. One way to prevent sweet spots is to stir up the top of the grain bed with a fork. You can go as far as halfway down the bed and not disturb it too much. But it's important to move gently. Some people might be afraid that this will disturb the bed too much. If you feel that way, this is by no means a necessary procedure. It just helps you get the most out of your extraction. Also, only fluff the grains early, during the vorlauf. Doing it later may cause settling of the disturbed layers in the grain bed, leaving you with a stuck lauter.

> "If the water does not get to a certain spot in the lauter bed, you will get what are called sweet spots. Sweet spots represent lost extract."

Finishing Up

So when do you stop lautering? You have been adding water for quite some time now. How can you tell when it is time to stop? There are two schools of thought on when to stop: When you reach a certain volume or when you reach a certain gravity. Of course if all goes well, you'd like to hit both at the same time. However, achieving this takes a lot of practice.

If you decide to aim for volume, the question becomes: Which volume is correct? This depends on how much energy you can stuff into your boiling kettle. If you are using a 5-gallon (19-L) fermenter, you need 5.5 to 8 gallons (21 to 30 L) of starting wort. Generally if you are boiling on a stovetop, you won't need much more than 5.5 gallons (21 L). That's because the boil on most conventional stovetops is fairly weak. However, if you're cooking on a propane burner, especially one of those 150,000-BTU flame throwers, and you have a large enough kettle to contain the boil, you can easily extract 8 gallons (30 L) of wort and boil it down to 5 gallons (19 L) in an hour. You will also get good hop extraction this way.

If you decide to aim for a specific gravity, you won't know in advance, especially when you first try this, how much volume you'll end up with. With time, as you get used to your system, you may become successful at predicting the volume.

However, aiming for specific gravity will make your results more consistent with the recipe, if you're using one. It will also make it easier to repeat your results the next time you brew the same beer.

The specific gravity method entails taking periodic gravity readings in the boiling kettle. The general method for this is to take a sample of wort, put it in the measuring device, and immerse a measuring device in ice or ice water until the temperature is correct. Then, take a gravity reading and throw the wort back into the boiling kettle. Continue to take gravity readings until you have reached the desired gravity. Keep in mind that the gravity after boiling will be higher than the gravity at the start of the boil. This is due to evaporation of water during the boil.

There is also a third method that is used to decide when to quit lautering. It involves neither volume nor gravity of the extracted wort. This one is

practiced by those fearful of tannin in their beer. This method involves either tasting or taking a gravity reading of the wort as it exits the lauter tun. It is generally accepted that when the readings get down to a specific gravity of 1.008, there are more tannins and other unwanted material flowing from the lauter vessel.

If you are tasting the wort, at the point when you can no longer perceive a sweet flavor the gravity ranges from 1.012 to 1.006, depending on your ability to perceive sweetness. If you fear tannin, stop the lauter at this point.

If you still need more water to reach the volume you desire, then you can make up that amount of water by using hot tap water, or take the excess sparge water and pour it directly into the brew kettle. The important point is that you are not losing too much fermentable sugar at this point. It is completely acceptable to use this practice. In fact, many professional brewers use this method.

Photo by Charles A. Parker/Images Plus

If you have lautered correctly, with the proper temperature sparge water, you will hopefully be left with a fairly clear wort that comes in near the recipe's target gravity, which can then be siphoned off into your brew kettle to be boiled.

Nothing But Time

What if the lauter is taking too long? First, it's important to emphasize that a lauter that goes too fast is a more common problem than one that goes too slow. If you lauter for 15 minutes, you're going to leave a lot of sugar behind, and your extraction efficiency will be closer to 50 percent than 60 or 70 percent.

If it's really taking too long, however, the two most likely reasons for a slow lauter are:

1. The grain was milled too fine.

2. The protein layer that forms on top of the grain bed has set thick and is restricting the flow of wort through the grain bed, thus leaving Lake Lauter in its flood stage.

Both of these problems are easily rectified. If your milling size is too small, simply make it larger next time. Many people try using a small milling size because they are dissatisfied with their yield and want to get more extract out of their grain. But a larger mill setting (the actual setting varies based on the type of mill and grain) combined with a slow lauter will result in substantial extraction.

The second problem, a protein layer on top of the lauter, is easily remedied by taking a fork and periodically stirring the top of the grain bed. A side note on this problem: Wheat is notorious for gumming up lauters, so expect some delays in lautering a wheat mash. Also, grind the grain a bit larger than normal for wheat beers.

There is yet one more way that you can slow your lauter down, and that is by sticking your lauter bed. This basically means that the wort is removed too fast from the bottom of the lauter, causing the top of the lauter bed to push down on the sieve. This stops all flow through the lauter.

The most common way that this happens is that people take a long tube from their lauter spigot and put it into their brew kettle on the floor. Then they open the lauter spigot. The wort in the tube creates a great suction and, whammo, a stuck bed is formed.

To get rid of a stuck bed, underlet the lauter by pushing water back up through the spigot. This helps clear the sieve holes. After underletting you should wait about five minutes, then resume lautering. For more about fixing a stuck sparge, check out the chapter on that subject in this section, which starts on page 53.

There is one last suggestion to make the lautering process easier: As soon as you are done using your lauter tun, clean it. Procrastination about cleaning the lauter tun will almost inevitably cost you more time next time you brew. Also, there tends to be a fascinating array of molds that are willing to spring up in as little time as a day or two if the lauter tun is left even partially dirty. BYO

Related Links:

• Lautering, the act of drawing the sweet wort from the oatmeal-like mash after enzyme action has slowed, is simple enough. Like any finesse operation, it gets easier with practice and benefits well from systematic measuring, tweaking, and trial and error. Try some of these easy tips for better lautering:
http://byo.com/story587

• Don't be thwarted by problems when you're draining the wort off the mash. Get some advice on overcoming lautering problems:
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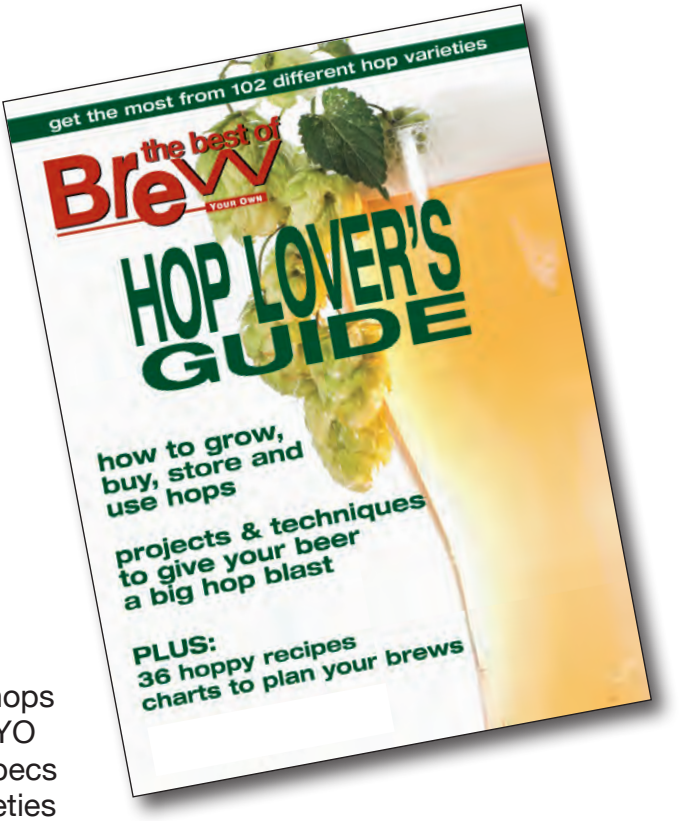

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Troubleshooting a STUCK SPARGE

Tactics for helping your wort go with the flow

by **Alex Fodor**

> “To avoid a stuck sparge, the bed of grain must be permeable to water.”

The flow of the sweet wort slows to a trickle and the start of the boil is pushed later and later into the day. When night falls, all your friends leave you high and dry with a stuck sparge and an empty soda keg. Such is the sad tale of the homebrewer whose run-off has mysteriously stopped. Fortunately, steps can be taken to avoid this fate.

Sparging is the step in all-grain or partial-mash brewing following starch conversion. The hot sweet wort sits in the lauter tun, intermingled with the grain particles. The purpose of running off the wort and then sparging what's left in the lauter tun with hot water is to remove the sweet liquid and leave behind the spent grains. Often this relatively peaceful event, involving the flowing of sweet nectar from hearty grains, is disrupted by subversive equipment or ingredients. In this section we will go over some of the likely culprits for a stuck sparge and how to remedy or prevent sparging problems going forward.

Mash Tuns and Malts

There are several different models of lauter tuns on the market. They range from a mesh bag in a plastic bucket to a converted keg with a stainless steel false bottom. Most mash tun designs will not directly be responsible for any stuck run-offs.

However, the speed of the run-off will vary between models largely depending on the surface area of the false bottom. A larger surface area means a shallower grain bed. The sparge water will run through a shallow grain bed faster because it has to travel a shorter distance to reach the bottom of the vessel.

If a homemade lauter tun is used, the holes of the false bottom should be about ⅛-inch (0.32 cm) in diameter. Anything smaller will slow down the flow; anything larger will allow too much solid material through, potentially

Photo by Les Jorgensen

A key to preventing a stuck sparge is making sure to control the flow of sparge water into the grain bed. If the bed runs dry it will collapse, preventing liquid from flowing through.

> “Rice hulls or unmalted husks will play a similar role in the filter bed as the malted barley husks, allowing for a smooth run-off.”

clogging the spigot.

Insulated lauter tuns, such as picnic coolers, have the advantage of keeping the liquid hot. This will keep the sparge moving along more swiftly and efficiently, because the sugars will dissolve better and the wort will flow more easily at a higher temperature.

Even the best lauter tun will not perform without properly crushed malt. To avoid a stuck sparge, the bed of grain must be permeable to water. The husk of the malted barley is the structural component of the grain bed that allows the bed to stay permeable. Without the husk the grain bed can be likened to a pile of mud. Having no use for mud, most brewers try to preserve the husk during the milling process.

The standard Corona flour mill tends to shatter the husk of the grain, often leading to stuck run-offs down the road. Roller mills keep the husk more intact while still crushing the grain effectively. A roller gap setting of 0.05 to 0.055 inch (0.13 to 0.14 cm) usually gives a good crush. If a roller mill is too expensive, a good homebrew shop will usually have one on hand for customers to use.

Brewers should also avoid overcrushing for fear of fines. After milling, crushed grains should contain intact husk pieces and small chunks of meal. Fines are the smallest particles produced from malt crushing and have the consistency of flour. Fines can form impermeable layers within the grain bed and impede flow.

Sometimes an all-barley-malt beer just doesn't suit your favorite style. So you try other mash ingredients, such as flaked wheat in a cloudy Belgian wit beer, raw barley in an Irish stout, or malted wheat in a German weizen. These are called adjuncts. When using adjuncts or malted wheat, which has no husk, the brewer must use extra caution to avoid a stuck sparge. In traditional weizens, up to 70 percent of the grains might be wheat malt, but don't think these brewers have an easy time of it. Lowering the quantity of wheat malt to 50 percent or less can relieve a sparging headache. Unmalted adjuncts, such as flaked wheat or oats, may be used cautiously at proportions up to 50 percent with a highly enzymatic malt such as six-row.

Unmalted adjuncts, such as barley or wheat flour, are typically problematic. Flaked or rolled grain is easier to handle than flour and is just as effective. Of all the adjunct grains brewers use, raw barley is infamous for causing the stuck run-off blues. One or two pounds of flaked barley in a 5-gallon (19-L) batch of Irish stout is more than enough to keep the leprechauns out of the lauter tun (and the wort stuck in it, with the run-off at a standstill).

Filter Aids

In the past brewers mixed chopped hay and oat husks into the mash to help filtration — often at the expense of beer flavor. Although this is no longer practiced, homebrewers have discovered other mash filter aids in the form of barley husks and rice hulls. Rice hulls are the husk portion of the grain removed during processing.

Homebrewers can add one-half cup rice hulls or unmalted barley husks per pound of grain at mash-in when using wheat malt or a large portion of adjunct to prevent sparging problems. The rice hulls or unmalted husks will play a similar role in the filter bed as the malted barley husks, allowing for a smooth run-off. Whenever adjunct grains, wheat malt, or rice hulls are used, they should be mixed thoroughly with the malt. Mixing the crushed malt and the adjunct while they are dry ensures that no clumps of adjunct will block flow.

Water's Role

First, keep temperature in mind. While conducting the sparge it is important to make sure the sparge water is at least 168 °F (76 °C) and stays at least that hot throughout the run-off.

Second, the sparge water should not be alkaline, because this can cause proteins to coagulate and block drainage. If you're having stuck sparge problems it might be worth checking the pH of your sparge water. Adjusting the pH of to 5 to 5.5 will avoid this problem and decrease the extraction of harsh tannins from the grains.

Finally, maintain a proper volume in the lauter tun. The sparge water should be applied as needed to maintain an inch or so of water over the top of the entire bed. Don't let the bed run dry. When all liquid is drawn off, the grains are pulled by gravity against the false bottom and the grain bed collapses. When the sparge water is poured over the collapsed grain bed, it will have a much harder time filtering through the densely packed grains. Besides causing the mash to stick, rehydrating the collapsed bed may result in the channeling of water within the bed. When the water flows through distinct channels, it fails to extract the sugars throughout the bed and decreases the original gravity of the beer.

Clogged Spigots

When it seems like everything was done right but the open lauter-tun

spigot is still just dripping like a leaky faucet, it could be time for more extreme measures. At the start of the run-off, the spigot may become clogged with rogue grains that escaped past the false bottom or screen you use in your lauter tun. An easy way to solve this problem is simply to shut off the spout for a few seconds and open it. This will increase the liquid pressure behind the spigot and help flush out the grains.

The more daring brewer might attach a piece of plastic hose to the end and try to suck the grains out. This is not recommended. If the brewer fails to remove the hose from his mouth when a visible flow starts at the top of the tube, many important taste buds will be burned to death.

Another good way of dealing with jammed spigots is underletting. Underletting is the practice of introducing hot water from beneath the false bottom. It is also a good way to float the grain bed off of the perforated plates when they clog or stick.

Homebrewers can underlet using a bucket with a plastic spigot on the bottom. Secure a plastic hose so that it connects the spigots of the lauter tun and the plastic bucket. Pour hot water (168 °F/76 °C) into the plastic bucket and open the spigots. When you lift the plastic bucket above the mash tun, gravity will force the hot water under the plates in the lauter tun, clearing out any clogs and re-suspending the grain bed.

A Matter of Mash Mud

A stuck run-off may also be attributed to troubles with top dough or teig (German for "paste"). Teig is a layer of gray sludge caused by the accumulation of fines on the top of the grain bed during recirculation of wort and sparging. Teig, like fines and flour, is mash mud. However, it is not really a problem unless it builds up to a thick enough layer to keep water from passing through the bed.

If the teig builds up, the brewer may rake the top of the grain bed with a large fork or cut it across in lines an inch or so deep with a knife. This will allow water to bypass the teig and percolate down. Another way to keep the teig at bay is to not over-recirculate. Brewers recirculate a sparge to remove protein when their runnings are cloudy. Recirculating is time consuming and can build up a mighty teig. Set a time limit of 15 minutes or so for recirculation, and if the wort hasn't cleared, move on. Most of the proteins causing the turbidity will precipitate with a vigorous boil.

Photo by Les Jorgensen

If the grain bed is allowed to dry out, gravity will cause the space between the grains to collapse. If this happens, you can't simply pour more sparge water into the lauter tun as it may form channels that won't distribute evenly through the grains to properly extract sugar.

The Last Resort

If all else fails, a homebrewer has little choice other than to stir the grain bed. This option is not so bad considering that brewers who batch sparge stir as a rule. Add some extra sparge water to the lauter tun so that the top of the bed is submerged by at least two inches, then stir up the bed with a spoon or a paddle. The run-off may not be as clear as it is with an undisturbed bed, but at least a brew day isn't wasted. Next time you brew try to figure out why your sparge stopped flowing and keep changing the parameters until you don't have to resort to stirring with the spoon.

Sparging is the bottleneck of the brewing process. To a professional brewer a drawn-out sparge can make the difference between completing one or two brews in a day. Still, it is a slow process for a reason. Running off too fast can cause a suction from the bottom of the lauter. This may collapse the tiny passages through which the wort flows and result in a stuck mash. Furthermore, the sugars must be extracted by the hot water during the sparge. This takes time. The total recommended sparge time should be at least 50 minutes for a 5-gallon (19-L) batch. BYO

Related Links:

• Any grain can be used, to some degree, in homebrewing. The most commonly used adjuncts in brewing are wheat, corn (maize), rice, oats, rye, sorghum, and potatoes (yes, potatoes). Visit BYO.com to learn more about each of these extras that can be included in your all-grain brew as well as which adjuncts can cause some trouble in the lauter tun: http://byo.com/story1463

BATCH Sparging

Get sparging with less equipment

> “Batch sparging has some advantages in terms of time, equipment required and efficiency.”

by **Brad Smith**

For homebrewers first getting into all-grain brewing, the terminology, technology and wide variety of methods can be confusing. Simplifying the process, especially for the first few all-grain batches, is important.

All of the technical jargon hides two pretty simple steps: Mashing and lautering. Most homebrewers use a single infusion mash, which means you add some hot water to your crushed grains to achieve a target temperature of somewhere around 152 °F (67 °C) for the mixture, and then hold it there for an hour or so. Heating the grain-water mixture up and holding it allows some natural enzymes in the grains to break down long unfermentable sugar chains into short ones (maltose) that yeast loves.

The second step is technically called lautering, though it is often loosely referred to as sparging. Lautering is the “larger” term encompassing the entire three-step process of a mash out, recirculation and sparging. The purpose of lautering is to extract the sugary liquid we call wort from the spent grains so we can boil it with hops to brew beer.

There are several possible sparging methods, though we’ll be focusing in on batch sparging for this particular article.

Sparging Methods

Some homebrewers may be surprised to find out there are at least four sparging methods you can use to extract sugary wort from your grains after the mash. The most traditional is fly sparging, which we discussed in the last article. However, we’re going to go into detail in this article on batch sparging as it is probably the most popular option for homebrewers. But first, let’s take a look at the differences between the most common sparging methods.

Fly Sparging: A fly sparge involves continuously adding hot water to the top of the mash tun as it is drained from the bottom. This is the method most commer-

Photos courtesy of Denny Conn

Batch sparging is a method where hot water is added in large batches to the mash tun during the sparge and then drained fully to extract sugars from the grains.

cial brewers employ, often using fixed nozzles used to spray water in a cone pattern over the bed, or sometimes (although not nearly as often since the 1980s) with a spinning arm at the top of the lauter tun that sprays water over the top of the grain bed. The flow of water is carefully managed so that the same amount of water is flowing into the grain bed as is draining out.

No Sparge: In a "no sparge" technique, a larger mash vessel is used and enough water is added to the mash tun to account for a "full boil" volume when drained. Since all of the water is already in the mash tun, no sparge water is added, and instead the mash tun is simply drained off into the boiler after mashing.

Brew-in-a-Bag (BIAB): Brew-in-a-bag is a variation of no sparge, except that there is no separate mash tun. Instead the mash is done inside of a bag placed within the boil vessel. Like no sparge, enough water is added to achieve a full boil volume after draining the grains. So instead of sparging or adding water, for BIAB you just lift the grain bag out of the boiler after the mash leaving enough wort behind to brew. (Read more about using the brew-in-a-bag technique in this issue on page 30.)

Batch Sparging: Batch sparging is a popular technique with many homebrewers, and is a bit of a hybrid approach. This method uses a normal sized mash tun, but water is added in large batches to the mash tun during the sparge and then drained fully at each step (see the sidebar on page 58 for the process). Batch sparging has some advantages in terms of time, equipment required and efficiency, which is why it has become a very popular method.

The Advantages of Batch Sparging

Batch sparging has some advantages over fly sparging or even BIAB and no-sparge techniques. These include:

Minimal Equipment. You don't need a separate fly sparge arm, and you don't need the larger mash tun or pot associated with no-sparge or BIAB methods. For most batches, a 5-gallon (19-L) cooler with a false bottom is sufficient for a 5-gallon (19-L) batch of beer.

Simplicity. You don't have to manage the continuous flow of water and wort as you would in a fly sparge.

Traditional Water to Grain Ratios. You can batch sparge with just about any desired water to grain ratio, including the traditional ranges of 1.25–1.5 quarts/lb. (roughly 1 L of water per kg of grain). BIAB or no-sparge methods require the full volume of water in the mash tun, so you would have to mash at a much higher water to grain ratio.

Efficiency. If properly done, batch sparging can be nearly as efficient as fly sparging.

Time Saving. Because you simply pour and then drain water in the mash tun, batch sparging generally takes less time than fly sparging.

Batch Sparging Calculations

You can perform a batch sparge with minimal calculations. Assuming your mash tun size is not overly large, simply fill up the mash tun with hot water after the mash and drain it. Measure what you have so far in the kettle, and then add enough water to the second batch to achieve your desired pre-boil volume. For lots of homebrewers who aren't worried about the math, that's all you need to know.

However, if you want to be more specific, sparging with unequal batches is not optimal, and will generally result in lower extract efficiency. To achieve the highest possible efficiency you need to size your batch steps so each one has equal runnings — i.e. you draw the same amount of water from the mash tun at each step.

I'll describe the manual steps to calculate the volumes later, though you can easily make a spreadsheet or use brewing software to do these cal-

A stainless steel braid made from a water supply line inside of a mash tun will separate the wort from the grains when you drain the cooler.

You can attach the stainless steel braid in the mash tun with a bung placed in the drain hole of the cooler.

On the outside of the cooler, the braid is attached to a valve that will regulate the flow of wort when you drain the mash tun.

The Batch-Sparging Method

1. Add hot water (if needed) to the top of the mash tun. Stir up the grain bed very thoroughly but gently and do not foam.

2. Drain the first few quarts from the mash tun (the recirculation, also called the "vorlauf") and add it back to the top of the mash tun.

3. Now open the spigot and drain the rest of the wort from the mash tun into the boil kettle. Open your tap as much as you are comfortable.

4. Once it is empty, add a second batch of hot water to the mash tun, stir as you did in step 1, and drain it as well.

5. Repeat as needed until you have the desired volume of wort for boiling.

Each time you fill and drain the mash tun, it is considered a "step." For most beers, two steps are sufficient, but the exact number of steps will depend on the size of your mash tun and how much grain you are using for a given batch.

culations for you. If you are interested in doing the math, however, here are the steps:

1. Estimate your pre-boil volume — how much wort you need to collect from sparging.

2. Determine how much of your mash water is absorbed by your grains.

3. Calculate the sparge volume available for mashing based on both your mash tun volume and grain bill.

4. Divide your pre-boil volume by the sparge volume available to determine how many batch steps are needed (typically two to three steps).

5. Evenly divide the water in the mash plus sparge water added to create equal runnings for each batch sparge step.

The first number you need to determine is your desired pre-boil volume, which is the amount of wort you need going into the boiler after sparging. Typically you get this by taking your batch size and adding in your trub loss and boil off losses. For a 5-gallon (19-L) batch you might lose a few quarts (liters) to trub and a few more to boil off, so your pre-boil volume would be in the 6.5-gallon (24.6-L) range.

Pre_Boil_Vol = Batch_size + Boil_losses + Trub_losses

Grain Absorption

Next we need to know how much wort we already have in the mash tun that can be drawn off during the sparge. This we can calculate from the water added for the mash, minus a portion that gets absorbed by the grains. The grain absorption can be estimated as 0.12 gallons/lb. or 1 liter/kg of grain.

Grain_absorb = 0.12 gal/lb. x lbs._of_grain

So let's pretend that we have 10 lbs. (4.5 kg) of grain in our recipe, and mash in with 1.5 quarts/lb. or 15 qts. of water (3.75 gallons). The water absorbed by the grains is then 0.12 x 10 = 1.2 gallons of water. So this means that the most wort we can draw from the grain bed after mashing is 3.75 - 1.2 = 2.55 gallons without adding more water.

Mash Tun Volume Available and Sparge Steps

The next step is to determine how many batch sparge steps are required to achieve our boil volume. Sparging with fewer batch steps is most efficient (two works for most beers) but if you are brewing with a lot of grains or a small mash tun, more steps are sometimes required. It depends on how large your mash tun is and how much grain you are using.

The grain itself occupies a certain volume in the mash tun — roughly 0.312 qt./lb. (0.652 L/kg) in addition to the water absorption we calculated above. If we add these together we get 0.792 qts./lb. (1.652 L/kg) that the wet grain occupies. So for a batch with 10 lbs. (4.5 kg) of grain, the wet grains take up 7.92 quarts (about 2 gal. or 7.5 L). This means if we are using a 5-gallon (19-L) mash tun to mash 10 lbs. (4.5 kg) of grain, we have slightly less than 3 gallons (11 L) of usable volume left per step.

Grain_volume_used = 0.312 qt./lb. x Lbs._of_grain

Sparge_vol_available = Mash_tun_vol - Grain_volume_used

We can now see how the mash tun size and amount of grain drives the number of steps. We simply divide the pre-boil volume by the sparge volume available to figure out how many sparge steps are needed. If we truly want 6.5 gallons (25 L) of wort pre-boil, we would be unable to get that in two batch sparge steps of less than 3 gallons (11 L) each, and would be forced to go to a third sparge step.

Number_sparge_steps = Pre_boil_volume / Sparge_vol_available

However, if we had slightly less grain, a larger mash tun or perhaps needed less wort in the boil, we could then fit our batch sparge into two steps.

Calculating Batch Sparge Additions

From the previous calculations, we now have everything we need to determine the water needed for each step, as well as the number of batch sparge steps needed. Using the example we followed earlier, we would need three batch steps to get 6.5 gallons (24.6 L) of pre-boil wort.

To maximize efficiency, you generally want the same amount of wort drawn from each batch step. So what we will be doing now is evenly spreading the water already in the mash tun plus the sparge water we will add across the three steps. The first step is the one where things are different, since you already have wort in the mash tun from the mashing process.

Desired_batch_step_vol = Pre_boil_volume / Number_sparge_steps

From our example, we determined our pre-boil volume was 6.5 gallons (24.6 L), and we need three steps. So the desired batch step volume to draw from each step is 6.5 gal/3 = 2.16 gallons (8.2 L). However, we already added 3.75 gallons (14 L) of water for the mash itself, of which the grain absorption was 1.2 gallons (calculated earlier). So 2.55 gallons (9.6 L) of wort is available in the mash tun, leftover from the mash itself.

So the 2.55 gallons (9.6 L) in the cooler is sufficient to cover the first batch step — we can simply draw the wort off the mash for our first step to collect the 2.16 gallons (8.2 L) desired. This leaves 2.55-2.16 = 0.39 gallons of wort in the mash tun.

So for our second batch step we want to draw the desired 2.16 gallons (8.2 L) off again, but already have 0.39 gal (1.48 L) in the mash tun, so we only need to add 2.16 - 0.39 = 1.77 gallons (6.7 L) of water to the second batch and then drain it fully.

For the third batch step, we again add the desired batch volume of 2.16 gallons (8.2 L) and drain it to finish collecting the wort for our boil. So even though we add different amounts of water for each step (zero, 1.77 gal./6.7 L and 2.16 gal./8.2 L) we are always drawing the same 2.16 gallons (8.2 L) of wort from each batch step.

Batch sparging requires very little equipment that most all-grain brewers already have. All you really need is a 5-gallon (19-L) cooler mash tun to brew 5-gallon (19-L) batches.

As I said earlier, you can use brewing software or a spreadsheet to simplify batch sparging calculations — you don't have to manually run these numbers unless you really want to. Also, you don't have to be super-precise with each addition if you are not as concerned about maximizing efficiency. You should just strive to draw about the same amount of wort from each batch step, and try to hit your target pre-boil volume so you have sufficient wort to finish your batch.

Considerations and Pitfalls

Some people are concerned about the efficiency of batch sparging, where efficiency is simply the percentage of potential sugars you can extract from the grains. Some brewers report slightly lower efficiency when batch sparging than they get with a slow fly sparge. My personal experience is that the efficiency for batch sparging is comparable to the numbers I get from fly sparging. However if you do get lower efficiency with batch sparging, you can compensate by adding a bit more grain to the recipe or lowering your brewhouse efficiency in your brewing software.

A second concern is a stuck sparge, which can occur when your grain bed gets compacted and actually stops the flow of wort from the mash tun. This is usually not a concern with barley based recipes but can occur when you are using a large percentage of cereal adjuncts such as wheat or oats. It is a higher risk with batch sparging than fly sparging, since you completely drain the mash tun for each step, and the grain bed is no longer floating. A potential remedy is to use rice hulls in the mash (which are flavor neutral) to maintain flow, or in worst cases to stir the mash to reopen channels in a stuck sparge. BYO

Related Links:

• Batch sparging is easy and convenient, but of course comes with its own drawbacks. *BYO*'s Mr. Wizard, Ashton Lewis, discusses some of the concerns to keep in mind when batch sparging:
http://byo.com/story176

• If you're looking for easy all-grain brew days, consider the countertop partial mash method of homebrewing — a hybrid of partial mashing, batch sparging and the extract late method:
http://byo.com/story507

NO-SPARGE Brewing

Skip the sparge for a simple brew day

by **Dave Louw**

> “No-sparge brewing is just what it sounds like. You skip the sparging step and just drain the wort from the mash into the boil kettle.”

A quest of mine to brew a flavorful but quaffable session ale was coming up short. I was getting wonderfully high extract efficiencies, near 90%, but my ordinary bitters, milds and Scottish ales were coming out watery and bland. Then I had a homebrew-life-changing experience with an ordinary bitter I judged in the first round of the National Homebrew Competition (NHC). The depth of malt character far surpassed anything I had been able to achieve, while the beer remained dry and highly drinkable. It was clear this was not just crammed with crystal malt. There was something I was missing.

I later found out that the beer won first place and was brewed by none other than Jamil Zainasheff (*BYO*’s “Style Profile” columnist.) This was extremely fortunate because I had brewed his exact recipe several times, so it meant there was either something different with his technique or ingredient sources. Ultimately, through an email exchange, I narrowed it down to a significant efficiency difference. Zainasheff did not just pick a 70% efficiency target to provide a common standard; he felt the beers were noticeably better compared to those brewed with extract efficiencies in the mid-80% range and higher.

In the following year I researched, experimented with, and refined my technique to consistently hit around 70% efficiency. Ultimately I settled on no-sparge lautering as the key. Everything came together for NHC 2009 when I entered my vastly improved ordinary bitter and won first place in the Southwest region. Since then I have used this technique on nearly all my beers and seen a significant increase in malt aroma and flavor complexity.

Photo courtesy of Denny Conn

No-sparge brewing skips the process of lautering all together. The brewer creates a thin mash that is then drained directly into the brew kettle after the mash is complete.

What Is No-Sparge Lautering?

Lautering is simply the process of separating the wort from the grains after mashing. Historically, commercial brewers discovered that if they sparged (rinsed) the grain bed with additional water during the lauter, they were able to get a higher yield of fermentable

sugar from the same amount of grains. This increased efficiency improved profits and so became standard practice for the vast majority of breweries.

Fast-forward to recent times and you will see that homebrewers commonly use either continuous or batch sparging when brewing all-grain beers. Continuous sparging directly scales down the commercial practice of adding water to the top of the grain bed while simultaneously draining wort from the bottom. It can be tricky to do consistently as matching flow rates, avoiding channeling and repeating the process identically batch after batch requires practice and/or specialized equipment. The pragmatic alternative of batch sparging instead involves adding water and draining the grain bed two or more times in sequence.

No-sparge brewing is just what it sounds like. You skip the sparging step and just drain the wort from the mash into the boil kettle. While that sounds simple — perhaps even lazy — the benefits can be numerous.

Why No-Sparge?

The primary reason I switched to no-sparge lautering was because of the flavor difference, especially lower-gravity beers. When compared side by side, I perceive a greater intensity of fresh malt character from beers I brew without sparging. By that I mean that the beer has an aroma and flavor that matches the aroma you experience when you open a new sack of malted grain. Surprisingly, this comes without the beer being perceptibly sweeter or more viscous, as you would get from adding lots of specialty grains.

I have yet to see a good explanation for why this is the case. Perhaps the uniformly higher gravity of the wort prevents some level of tannin extraction that comes from sparging. Maybe there is some difference about the first compounds that are extracted compared to those extracted during the tail end of rinsing. I just know what my taste buds and other drinkers tell me they perceive in the finished beer. Despite the added ingredient cost, there is at least one commercial beer produced this way — Kirin Ichiban.

Beyond the improvements to the beer, there are several practical benefits to no-sparge brewing. No-sparge brewing is simpler — you don't need to worry about matching the inflow rate of your sparge water with the outflow rate of your wort. No-sparge brewing also requires less equipment — you don't need a separate hot liquor tank (or HLT) or a sparge arm to deliver the sparge water.

This approach can save time too. While there are ways to speed up continuous sparging, it often takes 30–60 minutes depending on your target volume. With batch sparging you need to add water, stir and recirculate for each "batch" (usually there are two). No-sparge lautering skips all of this in that you simply recirculate (vorlauf) and then drain as quickly as you possibly can without sticking the mash. Of course, if your burner takes a while to heat up your runoff to boiling, this time saving may be moot.

In terms of difficulty, no-sparge is easy to do consistently and correctly. When I first started brewing all-grain, I was overwhelmed with all the variables in the process. Did I miss my gravity because I was having channeling? Was I sparging too quickly? With no-sparge brewing there is one less step to go wrong. With fewer variables in the process, there is subsequently less variability in the output. I consistently get 68–72% efficiency with beers in the 1.032 to 1.050 SG range. As the gravity goes up, the efficiency drops in a very predictable way.

From an equipment standpoint, no-sparge brewing means that you can skip the hot liquor tank and associated burner. Because you do not need to store sparge liquor while draining from the mash, the boil kettle is the only heatable vessel you really need. Additionally, the fluid mechanics of no-sparge brewing mean that, as with batch sparging, you can use a simple slotted manifold or braided hose rather than a more costly false bottom. In fact, an ideal setup is a large cooler with hose braid or manifold, a boil kettle and a burner. Set up the vessels on two levels so you can use gravity to transfer the wort.

Step by Step

Applying the no-sparge technique couldn't be easier. Start off by calculating how much water you need. While some homebrew sources warn against using a thin mash, there are actually some benefits. My experience matches what Kai Troester's experiments (seen at braukaiser.com) have shown: A thinner mash of 2.5 quarts of water per pound of grain (5.2 L/kg) or higher results in better conversion with no real drawbacks. In the interest of simplifying the process, add all your brewing liquor up front during the dough in.

There is no mystery or magic in figuring out how much water you need. Water added to the mash tun ends up in one of three places: in the boil kettle, pooled in the dead space in the tun or absorbed in the grain. To determine your total, you simply add up each part. My target pre-boil volume for a sixty-minute boil is 7.25 gallons (27 L). My mash tun has a dead space of about 1 quart (~1 L). That just leaves the water absorbed by the grain bed. An approximation that has served me well is that one pound of grain absorbs one half of a quart of water (roughly one liter of water per kilogram of grain.) So, for a beer recipe with 12 pounds (5.4 kg) of grain, I expect 6 quarts (5.7 L) of water to be absorbed and lost. Adding that all up for the theoretical batch on my system totals 9 gallons (34 L) of water.

Heat the entire volume of water to the desired strike temperature and transfer to your mash tun (or heat directly in your mash tun if possible.) Dough in and mash as usual. For my setup, I mash in a stainless steel kettle and so I need to heat and stir a few times to maintain my desired temperature, regardless of mashing technique. Doing this has the side effect of evenly dissolving the sugars throughout the brewing liquor. If you do not normally stir your mash, you will want to do so at least once at the end of the mash to get the sugars mixed evenly. Recirculate a few quarts as usual until the wort runs clear.

Efficiency Estimation

Estimating your efficiency when brewing with no-sparge lautering involves a straightforward calculation.

First, how well do the starches in your grain bed convert to sugars and go into solution? If you follow a similar process from batch to batch this tends to be a fairly consistent number. One way to measure this directly is to measure the gravity of your wort in the mash tun at the end of the mash after stirring well and multiply that by the total volume of water in the mash tun at that time. That gives you the total number of gravity points and you can divide by the theoretical maximum number of points. This percentage is the conversion efficiency.

The second step is how well you get that sugar out of the mash tun during lautering. Since you have stirred up the grain bed to equally distribute the sugar in all of the brewing liquor your lautering efficiency is a simple percentage of how much you drain off compared to the total water.

You can also measure this lautering efficiency directly by multiplying the gravity of your wort in the kettle times the volume of wort in the kettle to get the total gravity points you have extracted. Compare this to the total gravity points you measured in the conversion step in the mash tun.

Your overall efficiency is then the combination of the conversion efficiency and the lautering efficiency.

The biggest change when increasing the gravity of your beer is an increase in the amount of grain you need and therefore an increase in the water retained by the grain. If I had a batch that required 18 pounds of grain then I would have 3 more quarts of water in the mash tied up in the extra 6 pounds of grain. I would be draining the same 29 quarts from those 39 quarts, translating into a 74% lautering efficiency and a 85% x 74% = 63% overall efficiency. So an increase in gravity requires an increase in malt and an associated increase in mash water, resulting in a lower overall efficiency.

Now comes the easiest part. Simply open the drain valve on your mash tun and let it transfer as fast as you want without getting a stuck mash. Just as in batch sparging, the actual speed is irrelevant because you are not rinsing, you are simply separating the wort from the spent grains. At this point, you should have the desired pre-boil volume and you can proceed with the rest of your process as usual.

Since your entire pre-boil wort volume is in the mash tun, you can easily check to see if you hit your target specific gravity by sampling wort from the mash tun. Once you get a negative iodine test, stir the mash and let it sit for a minute (to let the grain solids settle out a bit), then take a specific gravity reading. Your pre-boil gravity should be Cp=(CtVt)/Vp (where Cp is pre-boil specific gravity, Ct is target specific gravity, Vt is target post-boil volume, and Vp is pre-boil volume). If you have not reached your pre-boil gravity, let the mash sit and sample again after 5 minutes. You may be able to save extra time by not needing to mash for a typical 60 minutes.

One variant on this procedure is to retain enough water from your total water volume to perform a mash out. Before running off the wort, transfer the last bit of (boiling) water from your kettle to the mash tun. Stir the mash, then recirculate (vorlauf) after about five minutes. In addition to the usual benefits of a mashout, this can save you even more time, as you will be heating your wort from 170 °F (77 °C) to boiling instead of mash temperature to boiling.

The Drawbacks

Of course, if no-sparge brewing had no downside, brewers would never have developed the techniques and equipment to sparge, nor would they invest the time and energy on each batch. The obvious drawback is lowered extract efficiency. On a commercial scale, a 70% efficiency would be a big hit to profitability in what is a very competitive industry. A jump to 90% efficiency means a brewer can use roughly ¼ less grain. This is true on the homebrew scale as well, but in the grand scheme of things our costs are often less critical.

Since you need to use more grain and because you will put all your brewing liquor into the mash tun up front, your mash tun capacity can be an issue. A 10-gallon (38-L) cooler at 70% efficiency is able to make a 6-gallon (23-L) batch at 1.052 gravity when filled to its maximum. To increase the gravity, you can decrease your batch size to 5 gallons (19 L) and get closer to a 1.076 batch. Or, if you upgrade to a 15-gallon (57-L) mash tun, your possibilities are practically limitless for 6-gallon (23-L) batch sizes.

Another problem with having all the water in your mash up front is that if you like to do step mashes you have got more thermal mass to deal with (read more about step mashing on page 68 of this issue). This will require either more heat or time to bring the mash up to the next step. I personally do not do step mashes, so this has not slowed me down.

The final drawback is a bit more subjective. Brewers typically fine tune recipes without the effects of no-sparge brewing in mind. Skipping the sparge can lead to a beer that is out of balance. For example, I have had trouble getting that slightly tannic roasty character that I like in dry stouts. Instead, the subtly nutty and biscuit-like Maris Otter base malt masks. The solution is to adjust the amounts or types of grains. Consider switching some or all of your Maris Otter base malt for a domestic two-row, perhaps. Dial back crystal malts. Or, simply brew these beers using either continuous or batch sparging.

Keep No-Sparge on the List

Whether or not you decide to switch all your homebrews over to no-sparge lautering, this can be a useful trick to have in your brewing repertoire. Consider pulling this technique out for the times when you want to make a tasty beer that doesn't knock you over with an alcohol punch or weigh you down with excess calories. Or, you can also try using no-sparge to save time and simplify your process. BYO

LAUTERING Efficiency

Take control of how your wort goes with the flow

by **John Palmer**

All-grain brewers are always talking about brewing efficiency — how much wort they yield from their mash into the boil kettle. There are two components to brewing efficiency: mashing efficiency and lautering efficiency. Mashing efficiency is all about the conversion of malt starches to sugars. Lautering efficiency is all about the extraction of those sugars to the kettle. There are several factors that determine lautering efficiency, but they all boil down to uniformity of flow. (For more about calculating brewing efficiency, turn to page 87 of this issue.)

> "There are several factors that determine lautering efficiency, but they all boil down to uniformity of flow."

No-Sparge and Batch Sparging

At 75% yield (total extract), the first wort gravity is about S.G. 1.075–1.085 for the typical grist ratios that homebrewers use (1.3–1.5 qts./lb. or 2.7–3.1 L/kg). So, what is the best way to extract that typical 75% yield? The answer depends on your equipment and patience. The simplest way is to just drain it — and this is called no-sparge brewing, as you read about in the previous section of this issue. However, with no-sparge brewing, a proportion of the wort will be left behind in the wet grain and your wort pickup tube. To recover this extract, you will need to add more water to the mash, stir and drain it again. This is called batch sparging, which you read about in this issue in the section on page 56. Each time you fill the mash and drain the wort, you dilute the remaining extract in the grain bed and leave behind a proportion of that extract, diluted to the new concentration (just like re-using a teabag.) The efficiency of batch sparging is best when the volumes of the first and second runnings are equal, i.e., half of your desired boil volume. A single batch sparge in this manner should obtain most of the available extract (roughly 90%). If three runnings are collected, all at the same volume, the efficiency should improve by about 5%.

Batch sparging is a nice method because it is simply draining, nothing fancy about it, provided your grain bed has good permeability. A finely-crushed grist will convert very well and give a high yield, but it will lauter very slowly. Your grain bed permeability will affect your lautering capability, no matter what sparging method you use.

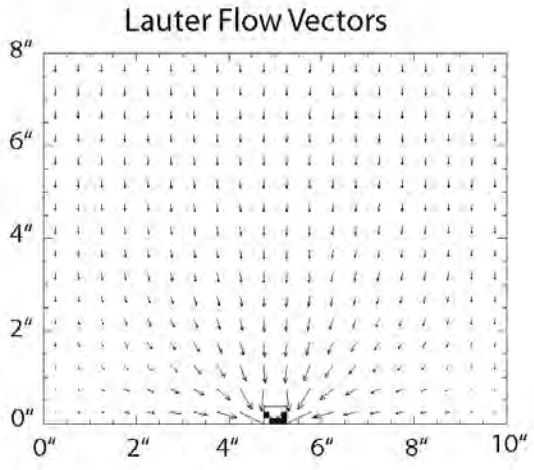
Draining vs. Rinsing

If you batch sparge, and fill the grain bed again, you dilute the sugars to a new concentration. The amount of sugar that comes out of the grain is a function of the concentration gradient between the solvent (water) and the solute. As the difference in concentration diminishes, the extraction of the sugar from the grain bed diminishes. The way to increase the extraction rate is to keep the concentration

Photo by Charles A. Parker/Images Plus

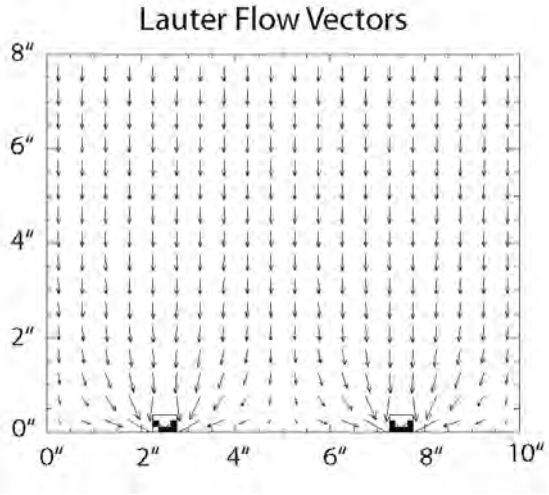
Lautering efficiency is the calculation of the extraction rate of the malt sugars from the mash into the kettle.

Figure 1:



Convergence of flow of a single slotted pipe or screen in an 8-inch x 10-inch (20-cm x 25-cm) grain bed

Figure 2:



Convergence of flow of a two-pipe or screen system in an 8-inch x 10-inch (20-cm x 25-cm) grain bed

gradient high, by constantly presenting water to the grain. Continuous or "fly" sparging is a rinsing process that works in this manner. The challenge with continuous sparging is making sure that all the grain is equally rinsed while also maintaining the flow of sparge water so that the grain bed does not collapse and stop the sparge.

The key to effective rinsing is uniform flow throughout the grainbed. The key to uniform flow is to maintain a steady state. The inflow should equal the outflow, and the permeability of the grain bed should be uniform so that water does not flow more easily through one side of the grain bed than the other. The inflow of water to the grain bed should be uniform across the surface area, and the easiest way to accomplish that is to maintain an inch (2.5 cm) or so of free water above the grain bed. Likewise, the outflow should occur uniformly across the grain bed area, otherwise the flow through the bed will vector toward the drain, leaving outlying areas unrinsed. A single collection point causes the most vectoring under steady state conditions and this behavior is shown in Figure 1 (shown at the top left of this page). Increasing the number of collection points reduces the amount of vectoring, and increases the uniformity of rinsing, as shown in Figure 2 (shown on the bottom left of this page).

Fluid mechanics gives us the science to quantify this effect, and we can build histograms of the relative amounts of flow occurring in the grain bed. These results are shown in Figures 3 and 4 (top and bottom on the right of the facing page). A computer model was constructed assuming an 8-inch (20-cm) deep by 10-inch- (25-cm) wide grain bed, and while that may seem small, it reduced the computation time, and the results are applicable to any size grain bed. The model calculated about 56% of the flow would be uniform for a single pipe manifold, and about 80% for a 2-pipe configuration. Increasing the coverage to 4 pipes improves the uniformity even further to 92%. The upper limit is found with a false bottom configuration. Its histogram is shown in Figure 5 (pg. 66), and

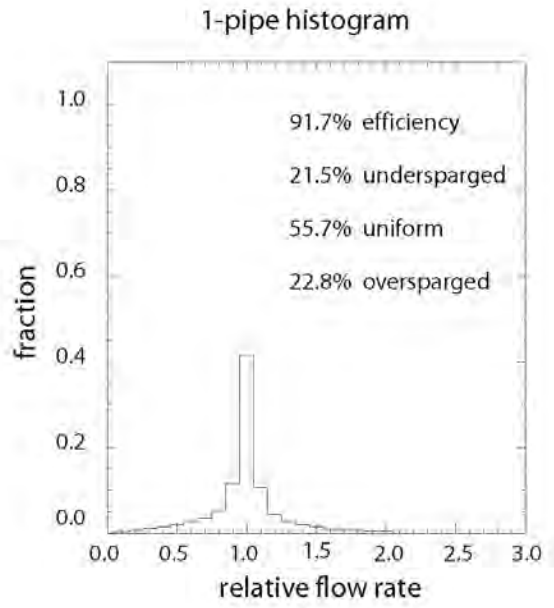
the uniformity is nearly 97%.

If you consider that the amount of extract in the grain is finite (i.e., once it's gone, it's gone) then we can estimate the efficiency of a lautering system by assuming that the percentage of extract from a region is equal to the proportion of flow that the region experiences, up to 100%. In other words, a 70% flow region will yield 70% of its total extract, and a 110% flow region will yield 100% of its extract. The model predicted about 92% of the volume lautered for a single pipe manifold, and about 96% for a 2-pipe configuration. Increasing the coverage to 4 pipes improves the efficiency to nearly 99%, which is almost equal to that of a false bottom at 99.7%.

The arrangement of the collection system is a big factor in flow uniformity. The examples I just discussed show that uniformity and efficiency improve with more pipes, but it's the arrangement and spacing of the pipes that make the difference. Uniformity is highest when the outflow area (floor of the lauter tun) is evenly divided by the pipes and when the pipe spacing is as close as possible. Imagine that the bottom of the lauter tun is 12 inches (30 cm) wide. Three pipes could be placed across the tun at 0, 6, and 12 inches (0, 15 and 30 cm), and that evenly divides the area (uniformity = 80%). But the flow convergence is reduced and uniformity optimized when the three pipes are moved closer together, and placed at 2, 6, and 10 inches (5, 15 and 25 cm) (uniformity = 89%). This balanced spacing arrangement increases the number of equal areas from 2 to 3 (actually 2 plus 2 halves).

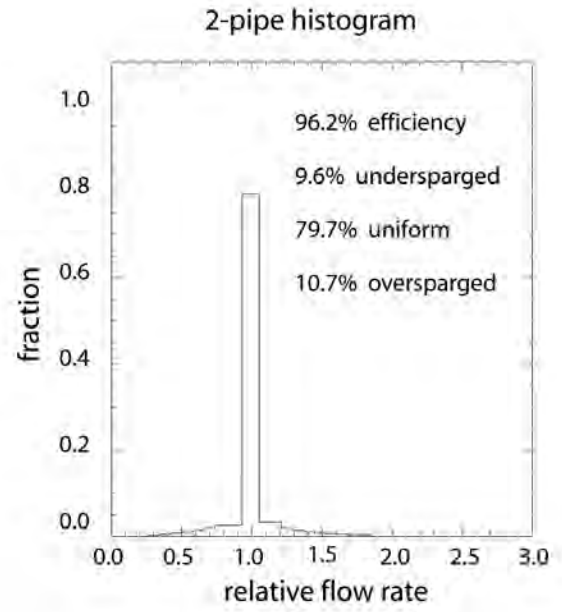
The same principle applies to round mash tuns, like a Sankey keg or beverage cooler. A single ring manifold works very well when it is sized to a diameter that divides the circular volume in half, and that equation is ring dia. = 0.707 x tun dia. It is interesting to note that the uniformity and efficiency of a false bottom does not surpass that of a single ring manifold until the false bottom diameter is greater than 80% of the tun diameter.

Figure 3:



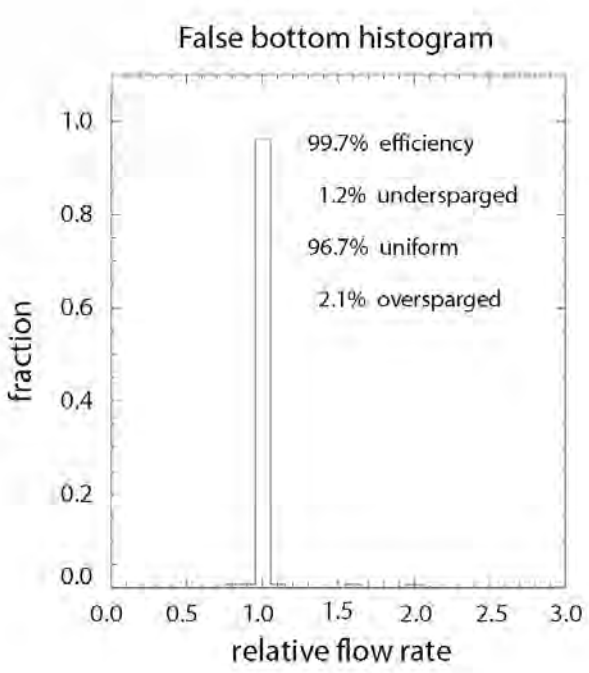
Histogram of the relative flow rates modeled in Figure 1

Figure 4:



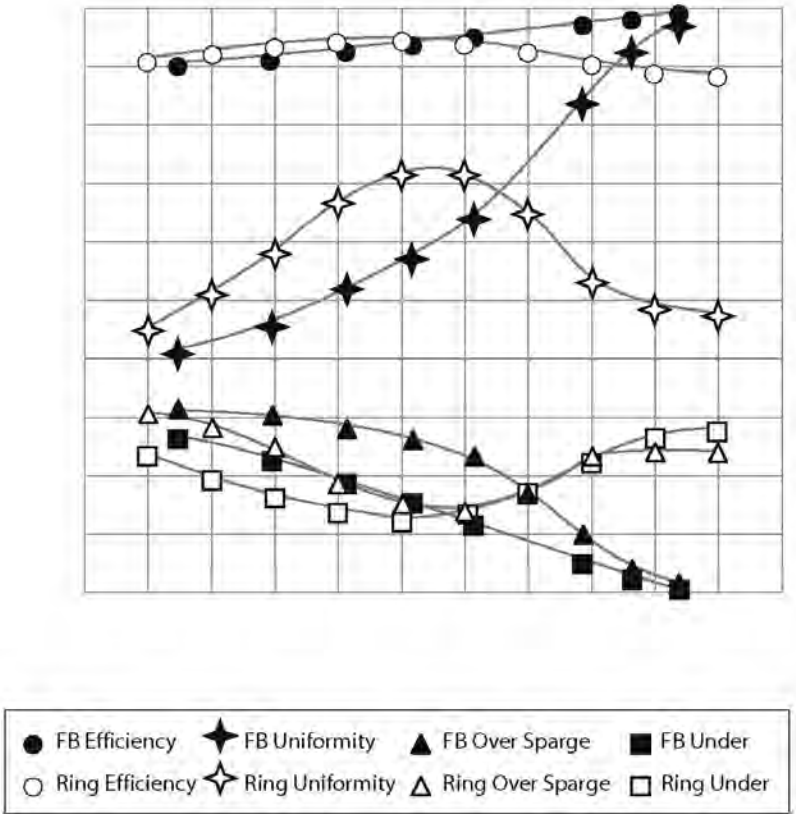
Histogram of the relative flow rates modeled in Figure 2

Figure 5:



Histogram of the relative flow rates of a false bottom in the same grain bed

Figure 6:



A comparison of sparging with a false bottom versus ring manifolds

The final factor to be considered in lautering (continuous or batch) is the flow rate. There are two reasons to run the lauter slowly. No matter what method or collection system you use, you need to start the flow slowly or you will tend to compact the grain bed around the device and impede flow. You want the main resistance to flow to be at the collection points (the holes/slots in the false bottom or pipes), not in the grain bed. If the resistance to flow is greater in the grain bed than in the collection system, the grain bed will compact and you will have a stuck sparge. This is especially true for false bottom systems. Second, when continuous sparging, you need to consider that rinsing involves diffusion and transportation of the sugar out of the wet grain. It takes a certain amount of time for this to occur and if your flow rate is too fast, you will simply run water through the tun and fill your boil kettle with water and not extract.

Not surprisingly, lauter tun design has been studied extensively by commercial brewers. In commercial lauter tuns, the rule of thumb is 1 to 1.5 outlets per square meter of lauter area and the flow velocity through the outlet should be very slow, about 0.1 meters per second, to prevent significant "pull" at the drain. (On a homebrew scale, one outlet is more than sufficient for a false bottom and wort is usually collected at the rate of approximately one quart (~1 L) per minute.) In commercial designs, lauter tuns usually have flat bottoms and the false bottoms cover the whole bottom. Homebrew solutions involving pipes or other manifolds inserted in coolers or kegs are less efficient than false bottoms. Their efficiency improves as the number and spacing of outlets approaches that of a false bottom — and pipe manifolds or other homebrew gadgets can certainly deliver an acceptable level of performance. If high lautering efficiency is the goal, continuously sparging your grain bed at a slow, steady rate in a lauter tun with a false bottom would be the best option. BYO

Related Link:

Get more pro advice for lautering:
http://byo.com/story590

Step Mashing
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Decoction Mashing
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Cereal Mashing
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Sour Mashing
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Turbid Mashing
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RIMS and HERMS
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ADVANCED ALL-GRAIN

Once you have a solid understanding of a basic all-grain brew day, you're ready to graduate into more advanced brewing techniques. In this section, you will discover how to step up to step mashing, and explore other mashing techniques such as decoctions, mashing with cereals and finally sour mashing.

Photo by Charles A. Parker/Images Plus

STEP Mashing

Manipulate your mash to produce distinctive styles

> “You can produce more variety and sometimes better, more distinctive beers when following a step mash program.”

by **Dave Green**

Step mashing is a mash program in which the mash temperature is progressively increased through a series of rests. The ubiquity of well-modified malts has virtually eliminated the need to perform a step mash in most situations. So why should you learn more about the process and science behind step mashing? Simple, you can produce more variety and sometimes better, more distinctive beers when following a step mash program.

Step mashing allows brewers to manipulate the mash to get the desired wort, dry or sweet, velvety or lightly astringent. You may also find that your extract efficiency goes up slightly-to-moderately when using a step-mashing regimen. Understanding the science behind step mashing can help all-grain brewers — and even partial-mash brewers — decide on an appropriate mash regimen for their beers. Step mashing requires the ability to heat your mash throughout the steps, either via a recirculating system (see more on page 82), by adding boiling water, or by performing a decoction (see more on page 73).

Malt Modification

The main purpose of malting is to begin germination of the barley, then toast the grain to stop the seed from sprouting. Brewers care about this because it will start two vital degradations and also produce the fundamental enzymes of mashing. During the malting process, gums (glucans) in the cell walls of the barley are broken down. Likewise, proteins are broken down. This breakdown supplies the wort with amino acids necessary for yeast health and lowers the possibility of haze or biological instability in the finished beer. Finally, malting causes the barley to produce the starch-degrading enzymes that will be employed in the mash. The degree to which gum and protein degradation has progressed is called modification. These days, most malts are fully modified. The glucans and proteins are degraded to a point that brewers only need to convert the starches in the grain to make good quality wort. Undermodified malts are those in which modification has stopped short, essentially leaving the brewer to complete those tasks in the brewhouse.

If a malt is undermodified, it will clearly say

Photo by Michael Pollio

Step mashing requires monitoring the mash temperature and stopping in stages along the way — known as rests — until reaching your conversion temperaure.

so in the name. For example, Briess makes a malt called Less Modified Pilsner Malt. Conversely, if a malt name does not mention its level of modification, it's fully modified. Seed barley is very hard. Malt modification proceeds from one end of the barley grain to the other, softening it. Another way to identify an undermodified malt is to chew it — if it has a hard, "steely" end, then it's undermodified. (Check out Table 1 at http://byo.com/story1497 for a summary of various malt types and their levels of modification.)

If you have purchased an undermodified malt — or have made your own malt at home, which usually yields unevenly modified kernels — a step mash (or decoction mash) may be your best option.

Enzymes

Enzymes are proteins that catalyze chemical reactions, allowing them to occur at a much faster rate than they would on their own.

A protein is a long, unbranched chain of amino acids, ranging from as short as about 50 amino acids long for insulin to up to over 8,000 amino acids in some of the largest proteins. In some regions of a protein, an amino acid sequence will form a "coil" (called a helix). In others, the string might double-back on itself and form what's called a sheet. The whole sequence, with its local regions of helices and sheets, folds into a 3-dimensional shape. The most common bonds that stabilize the enzyme's shape are known as Van der Waals forces, which are weak attractions that can easily be broken by increased temperature or changes in pH.

The shape of an enzyme determines its function. This is because the substrate for a given enzyme will fit into the enzyme's "active site." A simple analogy for enzyme action can be drawn using the video game Pac-Man. If the Pac-Man character was an enzyme, his mouth would be the active site, which would grip the substrate (or substrates) and catalyze a chemical reaction. For example, when an amylase enzyme breaks down a starch molecule, its active site "grips" the starch and breaks the bond between two sugar residues in the starch strand.

Unfortunately, analogies to 1980s-era video games sometimes have to be abandoned when the finer points of enzyme action are discussed. Contrary to what the Pac-Man analogy might imply, enzymes do not physically "chew" on molecules.

The protein-degrading and starch-degrading enzymes in a step mash work by a process called hydrolysis, which loosely translates as "breaking with water." For example, amylase enzyme will bind to two adjacent sugar molecules on a starch strand. When a water molecule bumps into the enzyme and substrate complex, the enzyme catalyzes a reaction between a hydrogen ion (H+) from the water molecule and one of the sugar molecules, and a second reaction between a hydroxyl ion (OH-) and the other sugar. Essentially, the bond between the two sugars is replaced with a water molecule, which splits into two parts, breaking the starch strand. Once the bond is broken, the change in the shape of the molecules in the active site causes the enzyme to release, where it is free to float around in solution until it bumps into another starch strand.

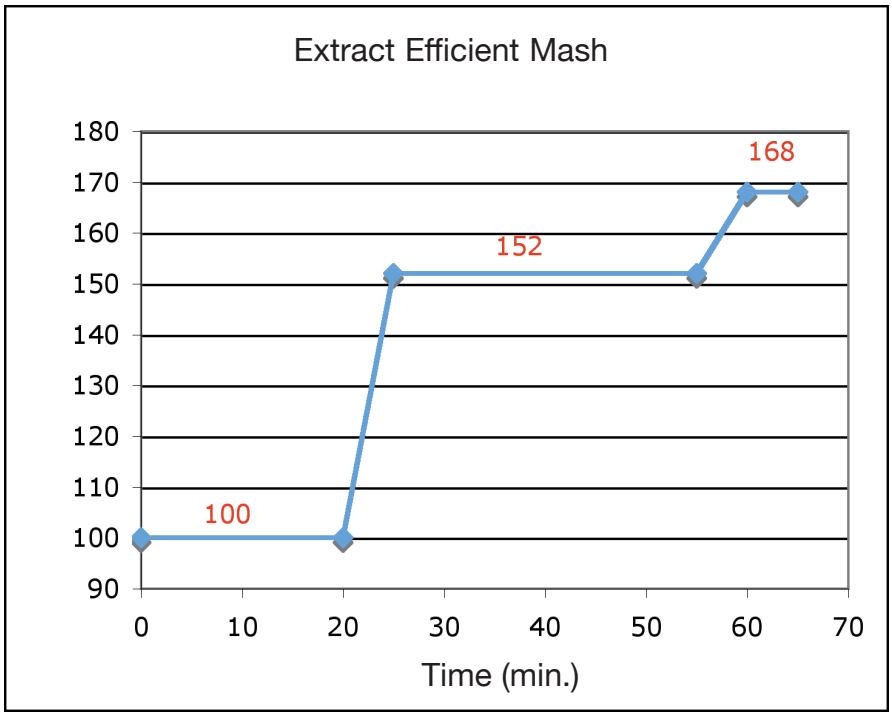
Now, if any of the bonds that stabilize an enzyme's shape are disrupted, then the enzyme will no longer function because the active site's shape changes and the substrate won't fit in it. When an enzyme's structure is disrupted by heat, we say that the enzyme is denatured. Once denatured, most enzymes — including the enzymes that are relevant to mashing — will not resume their active shape. Therefore, generally speaking, denaturing permanently deactivates an enzyme.

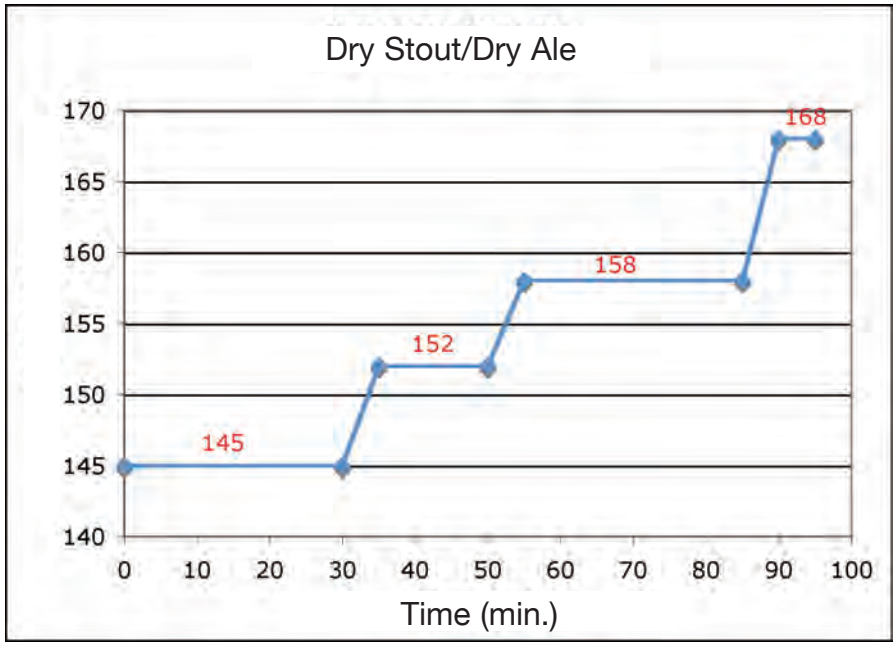
In the brewing literature, the optimal temperature ranges for various enzymes are given. (For a quick summary, see Table 2 at http://byo.com/story1497) For advanced brewers, it is important to understand what these mean. Enzymes are simple "machines" that work solely due to their shape. In solution, if they happen to bump into their substrate(s), they catalyze a chemical reaction. As an enzyme solution is heated, the rate of reaction increases as the time it takes for enzymes to randomly bump into substrate molecules is decreased because the individual molecules are moving faster through the solution. Enzymes are active at all temperatures between the freezing point of a solution and the temperature at which the enzyme denatures. When the temperature range for a given enzyme is stated in the brewing literature, it is the range of temperatures that result in good brewhouse performance for that enzyme. It does not mean that enzyme is inactive outside of that range. All brewing enzymes are active below their stated range. However, at lower temperatures, they are working more slowly. The top end of an enzyme's range is determined by the enzyme's activity and denaturation point. Heating a step mash over the top end of an enzyme's range does not cause that enzyme to stop working instantly. It takes time for enzymes to denature. In some cases, enzymes will actually denature within their stated range. For example, at 149 °F (65 °C), beta-amylase is denatured within 40–60 minutes and alpha-amylase activity will cease after two hours at 153 °F (67 °C). The point is that, by changing mash temperatures, you are not cleanly switching enzymes on and off. Due to their simple mechanism of action, your control over them is much more "squishy."

Still, there are four factors that determine the speed of an enzyme-catalyzed reaction — the enzyme's concentration, the substrate concentration, the temperature of the mixture and its pH — and all four of these can be manipulated in a step mash to alter your wort's qualities.

The Acid Rest

The acid rest is the first rest you might schedule after dough-in in any full step-mash or decoction-mashing regimen. The acid rest has two functions; to lower the pH of the mash to an appropriate range and to break down the dreaded glucans that can gum





up a mash. The typical range for an acid rest is between 95–113 °F (35–45 °C). At this temperature, the enzyme phytase breaks down a molecule called phytin and releases phytic acid, which lowers mash pH.

Phytase is very susceptible to heat and most of these enzymes will be destroyed during extended malting. So phytase will only be present in very lightly-kilned malts. Therefore it will only really benefit a mash made up of undermodified malts in soft water with little buffering capability — a rather small niche. Usually, this situation is addressed by simply adding acid to the strike water. Another reason that acid rests are not widely used is that it takes at least an hour to bring about any meaningful change in mash pH.

The second and more important purpose of a rest in this temperature range is to take care of the majority of glucans, also known as gums. Beta-glucans are a form of carbohydrates that are found in the protein layer surrounding the starch molecules in grains and beta-glucanase is an enzyme that will degrade these molecules. Various glucanases are active all the way up to about 140 °F (60 °C), but the most important glucanase, 1,4 beta-glucanase has an optimal temperature right around 113 °F (45 °C). Beta-glucans are found in highest concentrations in rye, wheat, oats and undermodified malts. Beta-glucans are also known to lead to haze in beer if not properly degraded.

In a fully-modified malt, the level of beta-glucans should not be a problem, but if you experience lautering problems or haze with your favorite malt, try a 15-minute rest in the acid rest temperature range.

The Protein Rest

A rest in the temperature range between 113–138 °F (44–59 °C) has traditionally been called a protein rest. These days, many brewing scientists do not think that much protein degradation occurs during mashing and this is part of the reason that it is left to the maltster. However, it's worth reviewing the possible enzyme actions that may occur in this range. There

are two specific types of enzymes that were thought to be active in this range — proteinase and peptidase enzymes, which are collectively known as the proteolytic enzymes.

Proteinase is an enzyme that works on longer-chained proteins turning them into medium length chains. Peptidase enzymes chop up the moderate to short chains and break them down to their component form. Conveniently, these two enzyme groups have slightly different optimal temperature ranges, so you can hypothetically favor one or the other.

Brewers do not want a lot of longer chain proteins in their wort. A high level of big proteins can lead to haze and instability. However, brewers do want medium length protein chains because they are beneficial for a beer's body and for foam retention. The optimal range for peptidase is between 113–128 °F (45–53 °C) while the optimal range for proteinase is 131–137 °F (55–58 °C). A 15–30 minute hold in the proteinase range was thought to diminish haze, but not negatively impact foam or body.

One important point to note is that the low temperature rests have been found to be more effective with thick mashes. Therefore you may want to mash-in when utilizing these low temperature rests between 0.8–1.0 qts./lb. (1.7–2.1 L/kg). You can then thin the mash with boiling water when raising the temperature to the saccharification rest(s).

Some beta-glucanase activity also occurs in the protein rest range and some brewers perform a "protein rest" for this reason. Unless you have a very good reason — for example, if you know you have a high-protein malt on your hands — avoiding a rest in the 113–128 °F (45–53 °C) range is probably prudent as you will potentially avoid problems with head retention. When brewing with undermodified malt, you should rest in the 131–137 °F (55–58 °C) range — at a minimum, it will break down some gums.

Whether or not meaningful amounts of protein degradation are occurring in this range, a rest here does affect the quality of your wort. For example, the time and stirring that goes on in a step mash may promote better extraction efficiencies — especially for homebrewers not used to stirring their mashes or those who typically get marginal extraction rates.

The Iodine Test

An iodine test is a simple test that all-grain brewers can use to improve the quality (yield) and consistency of their batches. The test indicates the conversion of starches to brewing sugars in the mash. The iodine method produces distinct color reactions between an iodine solution and the different dextrins that accompany complete conversion.

The iodine test, also called the starch test, consists of adding a drop of tincture of iodine (found at any drug-store) to a drop of cold, clean wort on a white saucer. If the color remains iodine brown, the starch conversion is complete. A blue or purplish color shows the presence of starch, indicating conversion is not complete so the mash should continue.

When you are finished with your iodine test, do not return the sample to the mash, because iodine is toxic.

~ John Borlik

Starch Conversion

The only required rest in any mash program is a rest in the starch conversion, or saccharification, range. When mashing fully-modified malts, a single rest in this range is a popular option.

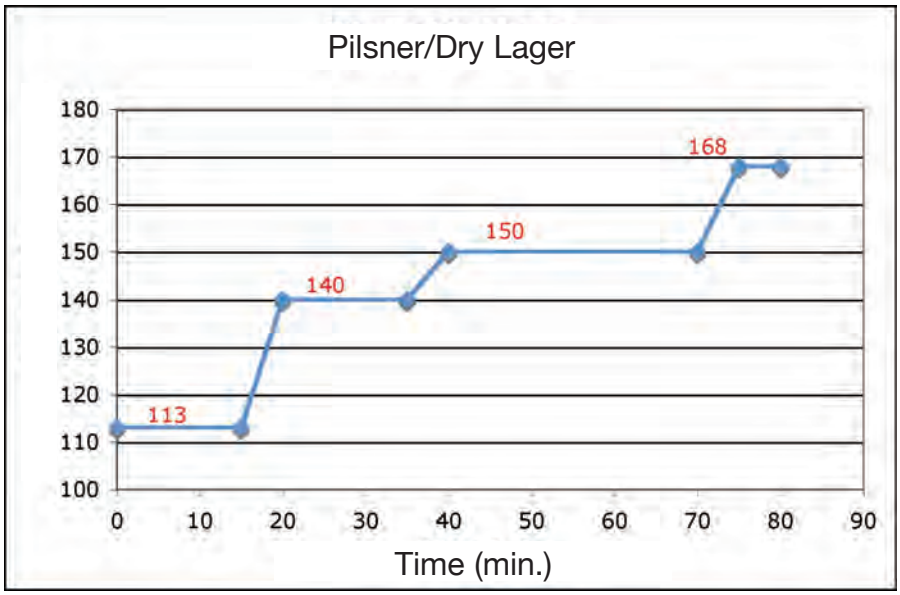
Starch conversion is performed by two separate enzymes, which attack starch chains in different manners. The two enzymes are collectively referred to as the diastatic enzymes. The typical starch conversion rest occurs between 142–162 °F (61–71 °C). (Sometimes you will see a smaller subset of this range stated, for example 150–158 °F (66–70 °C). Remember that enzyme action is not an all-or-nothing thing and allow for the fact that any boundary to any temperature range in brewing is arbitrary.)

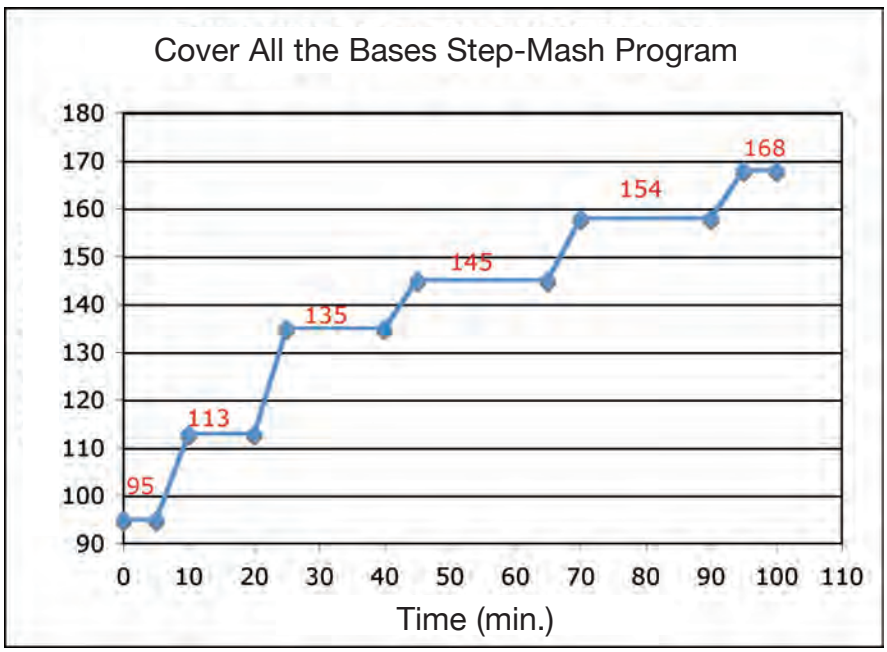
Beta-amylase attacks the ends of starch molecules and "snips" off the final two sugar residues, producing maltose. One noteworthy aspect to this is that starch molecules can be very long. If you want beta-amylase as your primary starch converter, then your mash will need a long rest in its optimal range. A 1–2 hour rest in the 140–145 °F (60–63 °C) range is one way for brewers to produce a highly-fermentable wort for drier beers.

Alpha-amylase is the second enzyme that is used for starch conversion. The optimal temperature range of alpha-amylase is around 155–162 °F (68–72 °C), although it is still active to a lesser degree at lower temperatures. Alpha-amylase attacks starch molecules at random points along their chains. It is bulky enough that it is not able to attack the starch molecules around branching points. A rest in the high end of the alpha range will result in a less fermentable wort, resulting in a sweeter, more full-bodied beer. In particular, a short (20 minute) rest at 158–162 °F (70–72 °C), in a relatively thick mash (around 1.0 qt./lb. or ~2 L/kg) will produce a very thick, full-bodied beer. This is particularly true for beers brewed with low-enzyme malts, such as British pale ale malts.

Alpha-amylase is usually used in conjunction with beta-amylase to produce moderate to full-bodied beers. The basic idea is that the "random" action of alpha amylase opens up new ends for beta–amylase to work on. Working together in the 150–152 °F (66–67 °C) range, these enzymes will produce a moderately fermentable wort and this is a popular range for single-infusion mashes among homebrewers. Increasing this temperature up to 154 °F (68 °C) will result in a more full-bodied beer, but not so "thick" as to be sweet or cloying.

Typical resting time is 60 minutes, but with many malts, conversion occurs more quickly than this. For a moderate to full-bodied beer, you can begin running off the wort as soon as an iodine test (see sidebar, above) shows a negative result (no color change, indicating that there are not appreciable amounts of starch.)





Alpha-amylase is less active and less stable in worts with low levels of calcium ions. This instability is increased in thin mashes and mashes in which the pH is above the recommended range.

For any beer that is supposed to be full-bodied, a mash out — a 5-minute rest at 168–170 °F (76–77 °C) — is recommended. Also, ensure that your grain bed temperature stays at this temperature during sparging by heating your sparge water to the appropriate temperature, which is dependent on the heat loss of your system during lautering. This will ensure that amylase enzyme activity is decreased, due to denaturation of the enzymes. As such, your wort fermentability will not increase appreciably during wort collection due to continued enzymatic action. Performing a mash-out also increases wort viscosity and makes lautering easier.

Step Up to the Plate

The figures shown on page 70 and on this page to the left show some suggested step mash programs for a select few styles of beer. Most homebrew texts also list various combinations of steps.

When deciding on a mash program, you need to consider your malt type, your beer style and its desired characteristics and sometimes even your brewing setup. Keep in mind that a more complicated mash program does not necessarily result in better beer. Conversely, if you have been experiencing poor lautering, haze, low extract efficiency or worts that are not as fermentable as you would like, adding the appropriate rest to your mash may solve the problem. When using undermodified or homemade malt, you will need to do a step mash — at a minimum, you should hold in the protein rest range before boosting the temperature to the starch conversion range. The more undermodified or variably modified your malt is, the more an involved step mash will improve yield and wort quality. Take notes during your step mashes and use them to improve successive batches. BYO

DECOCTION Mashing

Make a malty wort the old fashioned way

by **Chris Colby**

Almost all modern malts are well modified and respond well to a single infusion mash when an all-malt beer is being brewed. But sometimes you will come across a malt or recipe where a single infusion mash is not appropriate.

The mash temperature of a single infusion mash is almost always in the 148–162 °F (64–72 °C) range. Step infusion mashes, in which the mash is rested at two or more temperatures, may be accomplished by heating the mash directly or adding infusions of boiling water to raise the temperature between rests. A common single step mash is one with a rest in the beta-glucanase range (113–122 °F/45–50 °C) followed by a rest in the saccharification range (148–162 °F/64–72 °C).

If adjuncts such as corn grits or rice are used, a double or cereal mash is employed (read more about cereal mashing in this issue on page 76). In essence, the cereal adjunct is cooked separately to rupture the starch granules in the grains. Then the cereal mash is returned to the main mash, which is composed of barley malt with high enzymatic content. (The type of malt used in conjunction with large amounts of adjunct is usually 6-row malt. Purified amylase enzymes may also be added to aid with starch conversion.) Because the cereals are added to the main mash at near-boiling temperatures, the temperature of the combined mash increases and double mashes are thus stepped mashes. (Flaked or torrefied grains are adjuncts that can simply be stirred into a mash.)

A decoction mash is a step mash that is performed by removing a portion of the mash, boiling it and returning it to the main mash. Traditionally, decoction mashing was used to get the most out of malt that was not produced to today's levels of modification. In the past, malt was both less modified and more variable with respect to degree of modification.

Decoction mashes may involve more than one cycle of separating (or pulling) a decoction, boiling it and returning to the mash. The traditional type of decoction mashing is a triple decoction mash, in which decoctions are boiled and returned to the main mash three times. As such there are four temperature rests, one at the temperature the grains are mashed in at and one after each decoction. Decoction mashing was developed before the advent of thermometers, and the triple decoction mash may owe many of its features to this fact.

Pros and Cons

Some brewers argue that a decoction mash yields a desirable malt characteristic in beer, particularly German and Czech-style lagers, — such as Pilsners, bocks, doppelbocks and Oktoberfests — that other mashing methods cannot duplicate. Pilsner Urquell is an example of a beer that is decoction mashed.

Other brewers see decoction mashing as a huge waste of time and energy (as in

“A decoction mash is a step mash that is performed by removing a portion of the mash, boiling it and returning it to the main mash.”

Photo by Charles A. Parker/Images Plus

Decoction mashing is a step mashing method that was developed before thermometers and before the well-modified malts that are available to homebrewers today.

> “Some brewers argue that a decoction mash yields a desirable malt characteristic in beer, particularly German and Czech-style lagers . . .”

BTUs), and some dispute the contention that decoction mashing produces a character that cannot be obtained any other way. A triple decoction mash is very time and energy consuming and most commercial breweries that once performed this type of mash have either shortened their mashes to double decoction or single decoction mashes, or have begun infusion mashing. Most brewers, however, will agree on the following points.

Decoction mashing results in some melanoidin production. Melanoidins are red-brown, aromatic compounds formed by reactions between amino acids and sugars. They are formed at temperatures over 194 °F (90 °C). Both Munich malts and — big surprise — melanoidin malts are rich in melanoidins, and some brewers argue you can mimic the effects of a decoction mash by adding a portion of these malts to your grist. In pale beers, brewers attempt to minimize melanoidin production. In darker beers, they look for ways to increase it. Since parts of the mash are boiled in a decoction mash, and wort boils at around around 215 °F (102 °C), melanoidins are produced. The degree to which they are produced depends on how intensely the decoctions are boiled and the levels of protein modification (and hence the availability of amino acids) in the malt. Decoction mashing extracts more tannins than an infusion mash. Along with gelating the starch, boiling the mash extracts husk compounds, including polyphenols (tannins). The level of tannin extraction, however, is fairly low and some maintain that this low level actually benefits the flavor of the beer. If a low, pleasing amount of tannin extraction is a piece of “decoction mash character,” then simply adding Munich or melanoidin malt would not capture that character exactly.

Homebrewers used to infusion mashing may wonder how a decoction could be boiled without extracting a large amount of tannins and yielding a very astringent beer. After all, when lautering, they are repeatedly told that their grain bed temperature should never exceed 170 °F (77 °C). The key to understanding this apparent discrepancy is understanding when tannins are soluble in wort. Increased heat and increased pH both favor tannin extraction. At lower pH values, such as those found in a thick mash, tannin extraction from grain husks is minimal even at boiling temperatures. At higher pH values — such as those in a grain bed that has been extensively sparged — excess tannin extraction occurs at a much lower temperature.

Decoction mashing inactivates some of the enzymes in a mash. Enzymes are proteins (strings of amino acids) that are folded into a specific three-dimensional shape. The shape of the enzyme determines its function. When heated, enzymes unravel (or denature, in the lingo). Different enzymes denature at different temperatures because they assume different shapes and some are “cross-linked” by sulfur bridges that stabilize their structure. Boiling temperatures are sufficient to denature almost all enzymes and thus boiling the mash inactivates any enzymes that are useful in brewing. In decoction mashing, only roughly a third of the mash is boiled at each decoction and enzymes from the unboiled mash compensate for those denatured in the decoction boil.

Besides boiling of a portion of the mash, decoction mashing involves a lot of stirring and can result in an increased yield for many brewers. In a homebrewery, a decoction mash is likely to give the brewer a better yield compared to an unstirred single infusion mash.

Decoction mashing also results in increased removal of dimethyl sulfide (DMS), more intensive gelation of starch and less protein breakdown in the boiled portion of the mash. (Fewer proteins are degraded because the mash temperature of the decoction moves more quickly through the rests where proteinases are active than in the mash as a whole.)

Triple Decoction Mash

Although it takes some time and planning, it is certainly very possible to perform a triple decoction mash in a homebrewery. It does help, however, to have a brewing partner as you need to monitor what is going on in two mashes at the same time and the boiled mash needs nearly constant stirring.

Some maltsters sell less modified (or “undermodified”) malts, and these are a good malt choice when doing a triple decoction mash. You can triple decoct using modern, well-modified malts, but you may want to consider shortening some of the rests.

A triple decoction mash begins with a mash in at around 99 °F (37 °C). The mash thickness for pale beers is usually around 2.3–2.6 quarts of water per pound of grain (4.8–5.4 L/kg). For darker beers, a stiffer mash — around 1.4–1.9 qts./lb. (3.0–4.0 L/kg) — is used. Infusion mashes are generally thicker than both of these. As an option, the decoction mash can be mashed in very thickly at ambient temperature, then brought to the correct mash temperature and thickness

with an infusion of hot water. Try mashing-in in the kettle as this makes it easy to apply direct heat if you need to make a slight temperature correction.

These days the explanation for this temperature is often that it activates the enzyme phytase, which lowers mash pH. Of course, decoction mashing was pioneered long before enzymes were discovered. The choice of this temperature may be because it is easy to judge. At human body temperature — which varies, but hovers around 99 °F (37 °C) — water feels neither hot nor cold. Mashing in at this temperature may have been an adaptation to the lack of thermometers.

Next, the brewer "pulls a decoction." In other words, he or she scoops out the thickest one-third of the mash and heats it in a separate pot. You can do this after a short rest, around 15 minutes, or you can let the rest sit at 99 °F (37 °C) for (literally) hours. (If you want phytase to produce a noticeable change in mash pH, you may indeed need to rest here for hours.) Heat the decoction to 150 °F (66 °C) and let this rest for 15–20 minutes. This allows some starch conversion to occur before the decoction is boiled and the enzymes destroyed. In a modern, well-modified malt, the decoction portion of the mash may completely convert, or nearly so, at this step. Next, the decoction is heated to a boil. For pale beers, the decoction is boiled for 15 minutes. Dark beers, in which more melanoidin production is desired, are boiled longer — up to 40 minutes. You can boil your decoctions on a kitchen stove if you are worried about heating the mash too quickly and scorching it on a propane burner.

While any of the decoctions are being boiled, you must stir nearly constantly to prevent scorching. Although not traditional practice, you can add a pinch of calcium — either gypsum or calcium chloride — to the boiled decoction, to help the boiled mash achieve a desirably low pH.

After the first decoction is boiled, it is returned to the main mash, establishing a mash temperature around 125 °F (52 °C). (These days, we'd describe this rest as activating beta-glucanase. Older sources would likely call it a protein rest. With well-modified malt, you may choose to proceed directly to the next decoction.) After a variable amount of time — from roughly 15–30 minutes — a second decoction is pulled and boiled. Like the first decoction, this should be the thickest one-third of the mash. This decoction is boiled for 15–30 minutes and returned to the mash.

Once the second decoction is returned, the mash temperature should settle to around 149 °F (65 °C). Traditionally, the mash was allowed to rest for about an hour at this point. At this temperature, of course, starch is being converted into maltose and other sugars. If you are using a modern, well-modified malt, you can shorten this rest to 30 minutes.

After your conversion rest, a final decoction is pulled, boiled for 15–30 minutes and returned to the main mash for a mash out temperature around 170 °F (77 °C). A mash-out makes lautering easier — and lautering would likely have been more variable with historical malts. These days, we also know it brings most enzyme activity to a halt, "fixing" your carbohydrate profile. Now, you are ready to begin recirculation and lautering.

Other Decoction Programs

Shorter decoction mashes exist, both double and single. By varying the size of the decoction you pull and your mash-in temperature, you can come up with any set of rests you would like. If you mash in your kettle, you can also combine direct heat for steps or ramps within your decoction mash.

Schmitz Process

One single decoction program is the Schmitz process. This combines directly heated steps with one decoction to complete a step mash.

For a single decoction mash using the Schmitz process, mash in at 122 °F (50 °C), then heat the mash to 150 °F (66 °C). Stir the mash as you heat.

If you are making a dark beer, a long rest at ambient temperature — in German, a *vormaischverfahren* — may proceed heating the mash to mash-in temperature.

When you reach 150 °F (66 °C), let the mash solids settle. Once they are settled, carefully scoop out the liquid part of the mash — the part with the dissolved enzymes — and put it in another kettle. Keep this liquid at 150 °F (66 °C).

Boil the mash solids (and surrounding liquid) that were left behind for 15–30 minutes. Next, cool the mash back down to the point that, when you combine it with the liquids you are reserving, your temperature comes to rest within the saccharification range. Obviously, you would cool the grains down to 150 °F (66 °C) if you wanted the recombined mash temperature to be 150 °F (66 °C). If you wanted a higher temperature, cool the grains less. The exact amount depends on the proportion of water you scooped out to the proportion of grain left behind.

To cool your decoction, use a copper coil immersion chiller. Once you've added back the liquid part of the mash, you can use either direct heat or your immersion cooler to correct your temperature, if needed.

The first time you try brewing with a decoction mash, be sure to take good notes regarding the volumes of the decoctions you pull as well as the temperatures your recombined mashes settle in to. You can then use this information to tweak your plans for subsequent brew days. BYO

Related Links:

• A classic beer style that uses decoction mashing is doppelbock. Doppel is German for double and, although these beers aren't double the strength of a normal bock, their specific gravity is usually above 1.070. Dan Carey of New Glarus and Alec Mull of Kalamazoo Brewing Co. offer doppelbock tips (and recipes): http://byo.com/story283

• Decoction mashing is useful for making gluten-free beers as a little extra work in the mash will likely pay big dividends in terms of extract efficiency: http://byo.com/story698

CEREAL Mashing

Methods for brewing with starchy adjuncts

by **Jon Stika**

Mention the word "cereal," and most folks think of ready-to-eat breakfast food. To a brewer, cereal is the grain produced by any number of grass crops from *Avena sativa* (oat) to *Zea mays* (corn) that has not been sprouted to make malt. Cereal grains make up the greatest quantity and provide the most energy to the human diet, more than any other type of crop in the world. As brewers are well aware, barley in its malted form serves as the staple cereal grain of brewers worldwide because of its high enzymatic power when malted, and a husk that serves as a convenient filter following the mash.

But in a broader sense, what we are really engaged in when it comes to mashing is converting starch to sugar so it can be fermented by yeast. While the starch contained in cereal grain is in a fairly handy package, almost any starchy plant material from seeds to roots or tubers can be included in a mash as long as it is handled appropriately.

So why should you as a homebrewer bother concocting a cereal (or other type of starchy adjunct) mash to include in your brew? Historically, starchy adjuncts have been used in beer to add flavor, save money, or because of the sheer necessity of making beer with whatever starch source was available. Homebrewers today use cereals or other starchy adjuncts (hereafter referred to simply as adjuncts) for the same reasons, and also to exercise the creativity allowed by performing your own mash.

To explore the world of adjunct mashing you should first consider several questions: What style of beer do you plan to brew and how would various adjuncts complement that style? Are you going to perform a step mash or double (split) mash? What adjuncts do you plan to use and how should they be handled?

Cream ale or American lager are two beer styles that typically employ a mash with corn and/or rice. However, there are many interesting possibilities to explore by using either traditional or unusual adjuncts to modify existing beer styles or create something truly unique. Traditional adjuncts include corn, rice, and oats. Other adjuncts include sweet potato, pumpkin, sorghum, millet, and rye among many others.

> "Almost any starchy plant material from seeds to roots or tubers can be included in a mash as long as it is handled appropriately."

Photo courtesy of Wikipedia

Adjuncts such as oats (pictured as kernals, above) can bring a lot of possibilities to a homebrew; the trick is learning how to properly covert the cereal's starches into sugars.

The question of whether to perform a double mash with the main malt bill mashed as a single infusion (and the adjunct mash then added to it, hence the name double mash), or a step mash is largely a matter of equipment. A step mash works best if you have a mash vessel to which you can apply heat (i.e. kettle), and a double mash works best if you have a mash vessel to which you cannot apply heat but is well insulated (i.e. converted cooler). In either case the adjunct mash itself will be prepared in a separate pot that can be heated on a burner.

With either approach, an adjunct mash is prepared and then added to the main mash. With the step mash procedure, the main mash is held at a low enough temperature so that the temperature can be increased to starch conversion range even after the hot adjunct mash is added. With the double mash procedure you will not have the luxury of applying heat to the main single infusion mash other than by means of adding hot water. Because there are obvious limits on the size of the mash vessel and the desired consistency of the mash, a brewer cannot simply add excessive quantities of water to accomplish the task of adjusting the mash temperature. Therefore, some special attention needs to be paid to monitoring and adjusting the temperature with a limited amount of water after the adjunct mash has been added when using the double mash procedure.

There are various approaches that can be used in the double mash method to control the temperature of the single infusion mash to which the adjunct mash is added. One approach is to prepare a slightly thick single infusion mash near the low end of the starch conversion range (149 °F or 65 °C) and allow the boiling hot adjunct mash to raise the temperature of the whole combined mash nearer to the higher end of starch conversion (158 °F or 70 °C) temperature. When using this approach, keep some cold water or ice cubes on hand to cool things down if you overshoot the temperature somewhat.

Another approach is to allow the

Photos by Ian McKenzie

Flaked and torrified adjunct grains can be added directly to your mash. Although flaked grains have no amylase enzymes, excess enzymes from the barley can degrade the starch.

Photo by Derek Dellinger

One of the most commonly used adjuncts used in brewing is wheat, either torrified or flaked, which can create a variety of wheat beers, such as this wheat pale ale (above).

adjunct mash to cool down very near to the main single infusion mash temperature before combining the two. This should have minimal impact on either the temperature or consistency of the combined mash. If you are going to use a double mash system, take careful notes of quantities and temperatures when the adjunct mash is added and any temperature adjustments that were made to help predict or modify your process as needed in the future.

Now let's run through an example adjunct mash procedure using corn grits and a step mash system.

First, prepare your main barley malt mash as usual in a kettle on a burner except to start at 133 °F (56 °C) and reserve enough malt to include in the corn grit mash. Then hold the mash at that temperature while you prepare the corn grit mash in a separate pot.

Corn grits are commercially produced by soaking dried corn kernels in an alkaline solution, rinsing, and then drying and grinding them into meal. Polenta is coarsely ground corn. Cornmeal is de-germed corn ground somewhat finer than polenta. Any of these products can be used, but the polenta or cornmeal may require a longer cooking time than corn grits. Usually, grits are a bit easier to work with. Combine the grits with between 15% and 30% crushed barley malt (by weight) and enough water to get the mash to the consistency of soupy oatmeal in a pot on the stove and begin heating.

Stir the mixture frequently and add water if necessary to keep the consistency thin and prevent scorching. Bring the temperature of the mixture to the upper limit of starch conversion (158 °F or 70 °C) and hold it there for at least five minutes. This gives the modest amount of barley malt enzymes a chance to reduce the size of the starch granules and reduce their sticking together or causing the mash to stick to the pot.

The starch granules will then become coated with water, loosening hydrogen bonds and dissolving some of the amylose off of their surfaces. This will allow the starch to absorb water and become gelatinous or "gelate." This gelation is essential in order for the amylase enzymes of the malt to penetrate the starch in the grits and convert it to sugar after it is added to the main mash.

After the five-minute rest, continue to heat the corn grit mash to boiling, stirring constantly to prevent sticking or scorching. Boil the mash for 30 minutes to assure that the starch has absorbed enough water to gelatinize. Starch gelation occurs when starch is cooked in water between 140 °F (60 °C) and 200 °F (93 °C), depending on the type of starch.

Then, stir the corn grit mash into the main mash and heat the entire mash up to the desired conversion temperature, which is between 149 °F (65 °C) and 158 °F (70 °C). Hold the mash at the desired conversion temperature for at least 45 minutes before adding the sparge water and lautering as usual.

If you are going to use a starchy adjunct other than a cereal, be sure it is either coarsely ground or in small pieces that will gelate without an excessive amount of cooking (more than 30 minutes) to avoid a sticky or scorched mash.

Several starchy adjuncts often used in brewing are also available in flaked or torrified form. Flaked grain is steamed then rolled, and torrified grain is moistened and heated until it pops. Barley, rice, oat, wheat, rye, and corn (maize) are commonly available in flaked form, and wheat is readily available in torrified form. Both flaked and torrified grains have already undergone gelation and so can be added directly to a standard mash containing barley malt for conversion without prior mashing or cooking.

There is some debate in homebrewing circles regarding the differences in finished beer flavor between using cooked adjuncts or flaked/torrified adjuncts. While the flaked and torrified products may be more convenient and sometimes yield more extractable sugar than cooked adjuncts, many homebrewers argue that the cooked adjunct mash produces better flavor.

Related Links:

• Cereal mashing allows you to mash corn grits, rice or unmalted wheat for certain beer styles. It also allows you to experiment with virtually any starchy food. Read more about experimenting with cereals at home, plus: A "corny" cream ale recipe. http://byo.com/story442

• When you think "cereal" do you think Rice Krispies? Read about the confessions of a "cereal" brewer: http://byo.com/story484

SOUR Mashing

Harnessing bacteria to brew better beers

by **Dave Green**

Soured beers are gaining popularity among beer lovers and brewers alike. There are several methods you can employ to create a soured beer. Simple techniques include adding lactic acid to your brewing water or including acidulated malt to your grain bill. More advanced techniques include adding either cultured lactic acid bacteria or *Brettanomyces*, a mixed lambic culture of *Brettanomyces*, *Pediococcus* and *Lactobacillus* or oaking the beer with unsanitized oak ingredients while the beer is in secondary stages of fermentation. The final technique in the homebrewer's quiver would be performing a sour mash, which is what we will be discussing in this article.

The goal of a sour mash is to employ the work of *Lactobacillus delbrueckii* to a great extent while limiting the work of other critters such as fungi or bacteria like *Acetobacter* or *Clostridium*. You can accomplish this by pitching a live culture of *Lactobacillus*, by controlling the temperature of the mash and by limiting the oxygen introduced to the mash. *Acetobacter*, as the name implies, will produce acetic acid, the key acid in vinegar. *Acetobacter* will only play a significant role if the sour mash is incubated for an extended time period. You will know when *Acetobacter* has taken hold when the mash vessel, upon opening, has a cidery-like vinegar smell. While you would like to minimize the vinegar included in the mash, it will not spoil your attempts at creating a clean sour beer if kept in check.

Acetobacter needs oxygen and will only grow on the top of the mash. If you seal the top of the mash by laying some plastic wrap across the top, pushing all the air bubbles out in the process, then you can greatly decrease the opportunity for *Acetobacter* to act. *Clostridium* on the other hand produces butyric acid, which is a foul-smelling acid, faintly resembling my freshman year dorm, a mixture of rank locker room smell mixed with vomit. If *Clostridium* takes hold in the mashing vessel, it is rather apparent right away and make sure to keep away from significant others if you enjoy their company. I would advise dumping the mash if *Clostridium* takes hold. But some people seem to be okay adding this rank concoction to their beer stating that the odor can be boiled away. In general, a foul-smelling

> "The goal of a sour mash is to employ the work of Lactobacillus delbrueckii . . ."

Photo by Dean Croshere

Sour mashing is a technique that is employed to biologically acidify beer. The keys to sour mashing are controlling the mash temperature and limiting oxygen to the mash.

mash is going to yield a foul-smelling beer. A little "funk" in the mash is OK (some aromas will get scrubbed in the boil and fermentation), but too much and it should be discarded. Skimming the top of the mash can get rid of many off odors. A good sour mesh smells "cleanly" sour. *L. delbrueckii* produces lactic acid, an odorless acid that got its name because it is the spoiling agent in milk when lactose is broken down.

Before attempting a sour mash, you will need to get a pH meter and calibration kit, a thermometer and a small mash container that you can seal up tight. A small, insulated cooler will work in a pinch. This will also help regulate the temperature of the mash over the course of several days. If you have a space that can hold the temperature above 100 °F (38 °C) for several days, then you can also utilize a 1-gallon (3.8-L) jug or even smaller, depending on the size of your sour mash. One key to a good clean sour mash is that your container be filled right to the top for the incubation period.

So what type of beers might you utilize a sour mash for? Really the sky is the limit, but a short list of good examples would include, but not limited to Berliner weisse, lambic-styled beers, Flemish reds and browns, stouts, porters, summer ales, weizens, wits, saisons and the more obscure style, Kentucky common. The sour mash will add a nice twang to the beer if a moderate percentage of the total grain bill is added and a full pucker face if a large percentage of soured grains are added. Utilizing 5% of the total grist for the sour mash is generally the lowest end of spectrum. This is in the realm of using the sour mash for mash acidification. That means that if your recipe calls for 10 lbs. (4.5 kg) of grist then your sour mash would contain 0.5 lb. (0.23 kg) of your base grain.

The question on how much sour mash that one should add is really dependent on the brewing water you will be utilizing, the end pH of the sour mash, and the extent of sourness you are looking to achieve. The stronger the buffering capacity of your brewing water, the higher the carbonate levels, the more sour mash you will need to add to achieve your desired effects. A 10% sour mash using soft water may produce the same results as a 15% mash when hard water is utilized. Trial and error is really the only way a homebrewer will achieve their desired level of sourness. The end pH of the mash is also very important, especially to all-grain brewers because ideal mash pH should lie in the range of 5.2–5.4. Vermont Pub & Brewery's Greg Noonan advises, "a two-day sour mash will give a better flavor but half the acidity of a three-day mash." In acidified beers, the sour mash is stirred into the main mash to hit a proper mash pH. In sour beers made with a full sour mash (Kentucky commons, for example), the malts are mashed normally, then allowed to cool and sour. A brewer could also make a sour beer by stirring a large sour mash into the main mash after conversion has taken place. This would work well for moderately souring experimental beers. The percentage of mash that is soured will play the biggest role. Souring between 5–20% of the grain bill will give the beer anywhere from barely a touch of sourness to a nice twang. If you sour above 20% of the total grain bill, then you are entering true sour beer territory. Some homebrewers will sour mash upwards of 50% or more of their total grain bill. This quantity is ill-advised for anybody who doesn't want a true pucker-up beer or anybody that suffers from acid-reflux problems.

For first time sour mashers I would recommend souring between 5–20% of the total dry grist. This will give you something to work with for your next sour mashing session. Begin the sour mashing process two to four days prior to brewing the entire batch. Calculate how much of your base malt needs to be soured. You can use crushed 2-row, 6-row, pale ale, or Pilsner malt. Begin by heating 1.25 qts. (1.18 L) of water for every 1.0 lb. (0.45 kg) of grain in the mash, up to a temperature of about 162 °F (72 °C). In a pot, slowly mix the water into the grains and stir thoroughly. Wrap the pot in a towel and let the mixture stand for 40 minutes. After the 40 minutes, heat the mash up to 170 °F (77 °C) and hold for 10 minutes. Gently pour the mash into the vessel it will be stored in for the next several days, introducing as little oxygen is possible to the mash while pouring. The less oxygen introduced during this process, the less chance there is for mash spoiling critters to take control. Cover tightly with plastic wrap making sure to expel any air bubbles trapped on top and cool the mash down to roughly 115 °F (46 °C).

Inoculating (pitching the critters) in the sour mash is the final critical choice in the sour mashing process. The simplest and most straightforward technique is to keep a handful of dry grains from the preceding mashing steps, either crushed or whole grains work. Simply toss in the grains when the temperature of the mash falls below 120 °F (49 °C). The grains already contain the bacteria *L. delbrueckii* in their husks. Another way would be to pitch a culture of live bacteria. Both Wyeast and White Labs have made *Lactobacillus* strains available to homebrewers, or you may be able to find live cultures in some health food stores as packaged yogurt culture. Again pitch the culture when the temperature falls below the 120 °F (49 °C) threshold. Reseal the vessel and place in a warm spot. The closer you can keep the mash to the 120 °F (49 °C) mark without going over, the better your *Lactobacillus* will fare and the less likely unwanted visitors will take control.

On brew day, pour the sour mash through a strainer or colander to separate the grains from the liquid and add the sour liquid directly to the boil; or, if biological acidification is your goal, then add the sour mash to the main mash making sure the mash pH doesn't fall below the 5.2 threshold. Begin by mashing the grains as normal in your mash tun. You will want to heat the sour mash up to your first rest temperature to avoid any complications with volume and temperature of strike water to add. If your goal is to make a sour beer, then you can add more of the sour mash just after the saccharification rest but before lautering in order to raise the sour intensity. BYO

Turbid Mashing

Turbid mashing is a method that is still practiced in a few smaller lambic breweries in Belgium, such as Cantillon. If you have interest in brewing lambic-styled beers, wit beers, low-gravity or small session beers — or you just want to try an experiment — a turbid mash may push your beer to the next level.

Why Turbid Mash?

Turbid mashing is time-consuming, requires some specialized equipment and produces cloudy, starchy wort — something we homebrewers generally strive to avoid as starch causes haze and may lead to biological instability in our beers. So why would anyone want to try this in their homebrewery? A few of the reasons include:

Authenticity: Traditionally the lambic family, wit-styled beers and low-gravity ales from Belgium were brewed utilizing a turbid mash.

High Adjunct Proportions: Some lambic and wit beer recipes call for unmalted wheat in high proportion in the mash, and in some cases oats or rye. Ungelatinized raw wheat needs special treatment such as boiling or a glucan rest to be sure the lautering process proceeds smoothly. Turbid mashing should sufficiently breakdown the sticky glucans and large proteins found in the unmalted wheat, but leave the protein haze characteristic of wit beers.

Starch for Souring: If you are ready to delve into the world of lambic-style brews, or brew any kind of experimental sour beer, one key to getting a lot of sour character is to be sure there is still some unconverted starch left in the final wort. The starch will provide fodder for the microorganisms in a sour beer to work on after the brewer's yeast consumes all the simple sugars, such as maltose. Turbid mashing should leave a good concentration of unconverted starch in the wort.

Equipment

The basic turbid mash can be performed with one large (10 gallon/38 L) hot liquor tank (HLT), a smaller (~2 gallon/7.6 L) pot, a dedicated mash tun, a stuykmanden (read on) and a good mash paddle. You will also need another vessel, preferably the kettle, to hold the liquid first drained from the mash tun after the saccharification step has finished in the main mash.

A stuykmanden is a big basket used in Belgian brewing that is typically made out of wicker or copper that is lowered onto the surface of the mash through the top of the mash tank, where it acts as a strainer, allowing the liquid portion of the mash to filter through. At home you can use a colander. By pushing the colander down onto the top of the grain bed, free liquid from the mash will seep into the center bowl, which then can be siphoned out. Try to find a small, but deep colander which will fit in the top of your mash tun.

In The Brewhouse

The overall procedure of turbid mashing is fairly complicated, even compared to a decoction mash, so familiarize yourself with the schedule before jumping in. The first time you try this, focus on hitting the temperature marks first, and volumes and mash thicknesses second. The temperatures follow the basic steps found in many step infusion or decoction mashes, so feel free to substitute your favorite series of rests for those suggested here. Because most homebrew mash tuns have more than enough volume to hold the grains for a 5-gallon (19-L) batch, you will have plenty of space to thin the mash if the thickness becomes unmanageable. Take good notes and you will learn from your first turbid mash and be able to perform subsequent mashes more easily.

Dough in to 113 °F (45 °C). Your liquor to grist ratio at this point will be around 0.3 qt./lb. (~0.7 L/kg). Bring the water in the hot liquor tank (HLT) to a boil and, after the mash has rested 10 minutes, raise the temperature to 138 °F (59 °C) by stirring in boiling water. This should bring the mash to an overall thickness around 0.45 qt./lb. (~1 L/kg). Hold for 5 minutes at this rest.

Draw off about 1 qt. (1 L) of turbid wort (if brewing a 5-gallon/19-L batch of beer). Do this by sinking your colander into the mash and scooping or siphoning off the wort. An auto-siphon comes in handy for this. Do not collect any grain solids in this volume. (Skim them out with a strainer, if your colander lets some solid bits through.) Place the turbid wort in your small pot and heat it. An easy way to do this is to float the small pot in the boiling water in your hot liquor tank. You want the turbid portion to reach at least 180 °F (82 °C).

Now, stir in more boiling water to raise the temperature to 150 °F (66 °C). Hold at this temperature for 30 minutes, stirring often. The mash will still be thick, so you'll have to work fairly hard at this.

Next, it's time to use the colander again. This time, the mash is a bit thinner and you will collect about a gallon (3.8 L) of wort (again assuming you are brewing 5-gallons/19-L). Combine the wort you draw off with the first turbid wort in the small pot. Heat this portion in the small pot as before, aiming to raise it to at least 180 °F (82 °C). For the final mash rest, stir in boiling water to the mash tun and raise the temperature to 162 °F (72 °C) and rest for 20 minutes. While waiting to lauter, add water or otherwise cool the water in the HLT to 190 °F (88 °C).

Collecting the wort involves some unusual steps. First drain off some of the wort to the kettle — roughly the same volume that you have contained in your small pot. Replace the wort you ran off with the wort in the small pot. This should bring the mash temperature to 167 °F (75 °C). Hold for 20 minutes, then vorlauf and run off the rest of the wort, sparging with 190 °F (88 °C) water from the hot liquor tank.

From my experience with utilizing a turbid mash there are a few pointers to keep in mind to assure success when following the procedure laid out:

1. Before starting, make sure your stuykmanden (colander) fits in the mash tun.
2. Make sure that, by pressing down with the colander, you won't be bending any temperature probes or crushing any screens or manifolds.
3. Adding 0.5–1 lb. (0.23–0.45 kg) of rice hulls to the mash during the saccharification rest is a smart choice when using unmalted wheat. This is an added buffer to avoid a stuck sparge.

~ Dave Green

RIMS and HERMS

Recirculating Infusion Mash Systems and Heat Exchanger Recirculating Mash Systems

by **Bill Pierce**

Because our batch sizes are typically small compared to commercial brews, one problem many all-grain homebrewers have is maintaining their mash temperature. Ideally, mash temperature should remain relatively constant throughout each rest. Maintaining a specific temperature helps to control the fermentability of a beer, which in turn affects such qualities as body, finish and residual sweetness. However, even in a relatively well-insulated mash tun, it is not uncommon to experience a drop of 4–5 degrees Fahrenheit (2–3 °C) during the 45–90 minutes of mashing.

One solution to this problem is provided by two types of advanced all-grain systems: RIMS (Recirculating Infusion Mash System) and HERMS (Heat Exchanger Recirculating Mash System). In both systems, mash liquid is drawn off the grain bed, pumped past a heating element or heat exchanger, and returned to the mash.

> "Mash liquid is drawn off the grain bed, pumped past a heating element or heat exchanger, and returned to the mash."

Other Benefits

In addition to maintaining mash temperatures, a RIMS or HERMS can also be employed for raising the temperature of a mash in a step mashing program. Likewise, once starch conversion is complete, a RIMS or HERMS can facilitate the "mashout," in which temperature of the mash is raised to 168–170 °F (75–76 °C) and held for 5–10 minutes before sparging. In both these cases, the temperature is raised without diluting the mash, as when boiling water is added to raise the temperature of the mash.

Recirculating the liquid portion of the mash also helps to minimize the temperature differences during mashing. As the liquid diffuses throughout the grain, it equalizes the temperature. The recirculation and the heating of the mash liquid are therefore the basic principles behind all recirculating mashing systems.

In a RIMS, the heat source is an electric element placed in the recirculation loop to heat the mash liquid. A HERMS uses hot water as the heat source, usually incorporating a copper coil as a heat exchanger. The coil placed in the hot liquor

Photo by SABCO

An example of a 10-gallon Recirculating Infusion Mash System (RIMS).

tank (HLT) is used to heat hot water for sparging the mash. Both types of systems require a pump to move and return the mash liquid from the mash tun through the heat source and back again.

> “Both types of systems require a pump to move and return the mash liquid from the mash tun through the heat source and back again.”

RIMS: Electric Breweryland

The key to a RIMS is the heating element, which is placed in the recirculation loop. This requires building an enclosed chamber for the element, most commonly from copper pipe and fittings available at hardware stores and home centers. Some plumbing skills are required, but someone who has experience with basic home plumbing projects should be up to the task. The element itself is one used for electric water heating. A variety of replacement water heater elements are available in various lengths, sizes and wattage ratings.

Three factors are important in the selection of the heating element. The element voltage (120 or 240 volts) must be compatible with the electric service and wiring available in the brewing area. The element density (typically expressed in watts per inch or centimeter of length) must not be so high as to easily scorch the mash liquid. And the heat output (expressed in watts) must be sufficient to maintain or raise the temperature of the liquid. Heating elements rated for 240 volts may be used with 120 volts with a 75 percent reduction in output (to calculate the watts at 120 volts, divide the 240 volt rating by four).

To maintain the mash temperature in a RIMS, 1,500 watts is sufficient for 5–10 gallon (19–38 L) batch sizes. For step mashing, more power is required to raise the temperature quickly enough; 4,000–5,000 watts is not unreasonable. This almost certainly requires 240-volt electrical service and the appropriate wiring. A home dryer outlet, for example, is typically rated for 30 amps at 240 volts, for a total capacity of 7,200 watts (actually somewhat less to allow for overload).

Safety is very important when working with electricity in the presence of liquids. The heating element and brewing system must be well grounded to avoid electrical shock and consequences that can be fatal in the wrong circumstances. Even if you have a little bit of experience in this area, I strongly recommend having a professional electrician review your plans and inspect your construction.

A potential drawback of a RIMS is scorching of the mash liquid. This occurs at a temperature of about 480 °F (~250 °C) as the sugars begin to break down. Caramelization, which darkens the sugars and alters their flavor, occurs at a lower temperature that can be produced rather easily by electric elements. It is important to maintain an adequate flow of liquid past the heating element while it is on, so that scorching and excessive caramelizing do not occur. A little darkening is inevitable, but is not considered a major problem if kept to a minimum.

There is also some concern about denaturing of the mash enzymes. Alpha amylase, the primary enzyme in conversion of the malt starches to sugars, begins to denature at temperatures above about 160 °F (71 °C). However, the evidence is that it takes a considerable period of time before a significant portion of the enzymes are compromised. As a practical matter, the relatively short period of time the liquid is at a high temperature (it is quickly cooled as it is returned to the mash) does not cause a problem.

HERMS: Let Water do the Work

The possibility of scorching is eliminated in a HERMS because the temperature of the hot water in the hot liquor tank recirculation coil is far less than that of an electric heating element. There are also no electrical requirements for heating the mash liquid. However, there are other design concerns, such as maintaining efficient heat transfer between the hot water and the coil, and incorporating the coil into the HLT. Many HERMS also use a bypass loop to route the flow of the mash liquid around the coil when it is at or above the desired temperature. This requires a three-way valve, or two valves and plumbing tees so that the flow can be directed either through or around the coil.

The recirculation coil in a rudimentary HERMS can be merely an immersion chiller lowered into and removed from the HLT as needed. This has the advantage of simplicity; no drilling of the HLT and expensive bulkhead plumbing fittings are required. However, this is less permanent and somewhat less graceful for those who place a priority on elegant design.

The diameter of the tubing used for the coil is important to maintain an adequate flow rate and not stress the recirculation pump. Typically this requires a tubing diameter of approximately one-half inch (13 mm). As for the length of the coil, most homebrew HERMS use between 25 and 50 feet (7.5–15 meters). Incidentally, it is worth noting that soft copper tubing is usually measured by the outside diameter, as opposed to rigid copper pipe where the nominal size is the inside diameter. The builder needs to keep this in mind when selecting plumbing fittings and adapters.

The temperature of the water in

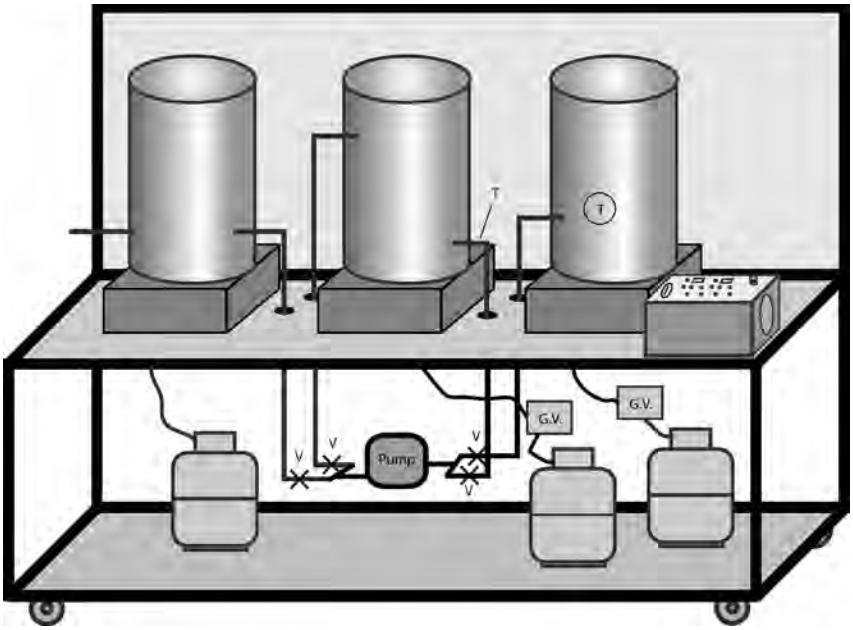


Illustration by John Palmer

The design plans for a HERMS. The system is controlled by a control box (to the far right, top). On brew day, the procedure would consist of pumping water from the HLT to the mash for the first infusion, stopping the pump to stir and dough-in, and then switching the valves and starting the pump for recirculation of mash liquid through a coil in the HLT.

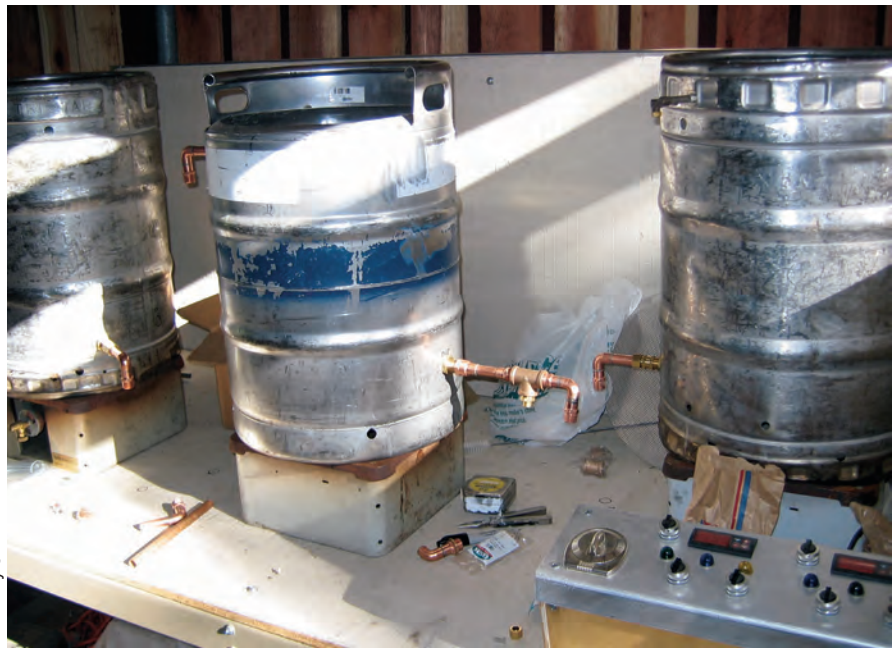


Photo by John Palmer

A RIMS or HERMS is built with three vessels, often placed on a brewstand at the same height as the pump moves the wort rather than gravity (such as in a three-tier system).

the HLT should be hot enough to transfer heat to the mash liquid in the recirculation coil. Assuming typical heat losses, this is approximately the same as the requirement for the sparge water, about 180 °F (82 °C). Stirring of the water during recirculation greatly increases the efficiency of the heat transfer. A few HERMS incorporate an electric motor and stirrer to accomplish this; other homebrewers stir the water manually with a long spoon or paddle. There is also convoluted copper tubing with interior ridges or fins that increase the turbulence of the mash liquid flow and facilitate the transfer of heat. Recirculation will gradually lower the temperature of the water in the hot liquor tank, very likely making it necessary to apply additional heat to the HLT occasionally during the process.

System Design Considerations

If a RIMS or HERMS is used for step mashing or mashout, it is important to design the system so that the flow rate and temperature increase are sufficient to accomplish the steps in a reasonable time period. Too slow a temperature rise between steps (less than 2 °F or 1 °C per minute) can adversely affect head retention of the beer, especially over the temperature range of 122–148 °F (50–65 °C). Avoiding this problem typically requires a flow rate of approximately one gallon (3.8 L) per minute. However, too high a flow rate creates suction on the mash and can compact it, causing a reduction in the flow or even stopping it altogether. This can be minimized by careful mash tun design-whether using a false bottom, manifold or hose braid — as well as by closely regulating the recirculation flow with a valve at the pump outlet. But it can make for problems if not considered and addressed.

One solution to mash compaction is to use a lauter grant. This is common in commercial brewing systems and consists of a smaller vessel placed below the mash tun outlet and before the recirculation pump. The grant is filled by gravity and the pump creates suction only on the grant rather than on the mash itself. For a 10–15 gallon (38–57 L) homebrew system, the grant can be a 4-quart (4-L) pot with inlet and outlet fittings attached. In automated systems, liquid level switches in the grant turn the pump on and off so that the grant neither overflows nor runs dry; manual systems require adjustment via valves regulating the flow to and from the grant.

Both RIMS and HERMS designs lend themselves to automated control systems. The subject of building electronic control panels is beyond the scope of this particular article, but see Walter Diaz's article, "Build an Electric Control Panel," on building an electric controller in the December

2013 issue of *Brew Your Own*.

Pumping it Up

As has been mentioned, both RIMS and HERMS require a pump to recirculate the mash liquid. A variety of pump types can be used; one of the most common for homebrewing applications uses a centrifugal pump with a magnetic coupling. In these pumps, the motor shaft is not directly connected to the impeller. Instead, a magnet attached to the motor shaft causes a corresponding magnet on the impeller to rotate as well. The advantage of such a pump is that it does not require a seal on the motor shaft and is relatively easy to keep sanitary. These pumps also are less prone to motor burnout because a disruption of the flow will not cause the motor to seize. Nor is a small amount of grain solids in the mash liquid a problem.

Centrifugal pumps are not self-priming and have very little lift, or ability to pull liquid up into the pump suction. For these reasons, centrifugal pumps are located below the vessel feeding the pump.

It is strongly recommended to use a pump rated for the temperatures involved, at least 180 °F (82 °C) for the recirculating mash liquid. The cost of such pumps is in the range of $150–$200 and they are available from some of the larger homebrew suppliers.

Other considerations with a RIMS/HERMS include piping, hoses and connectors. Some systems are plumbed with copper, brass or stainless pipe, while others use reinforced food-grade vinyl hoses. One is not necessarily better than another: Pipe is rigid and relatively permanent, while hoses allow greater portability and flexibility. In general, a diameter of one-half inch (13 mm) is best for homebrew systems. Plumbing with smaller diameter pipe, tubing or hose can cause flow and pump problems.

Quick disconnects can be used to facilitate frequent attachment and removal of hoses. Food grade plastic disconnects that are rated for the temperatures involved are usually available from larger homebrew suppliers and industrial distributors.

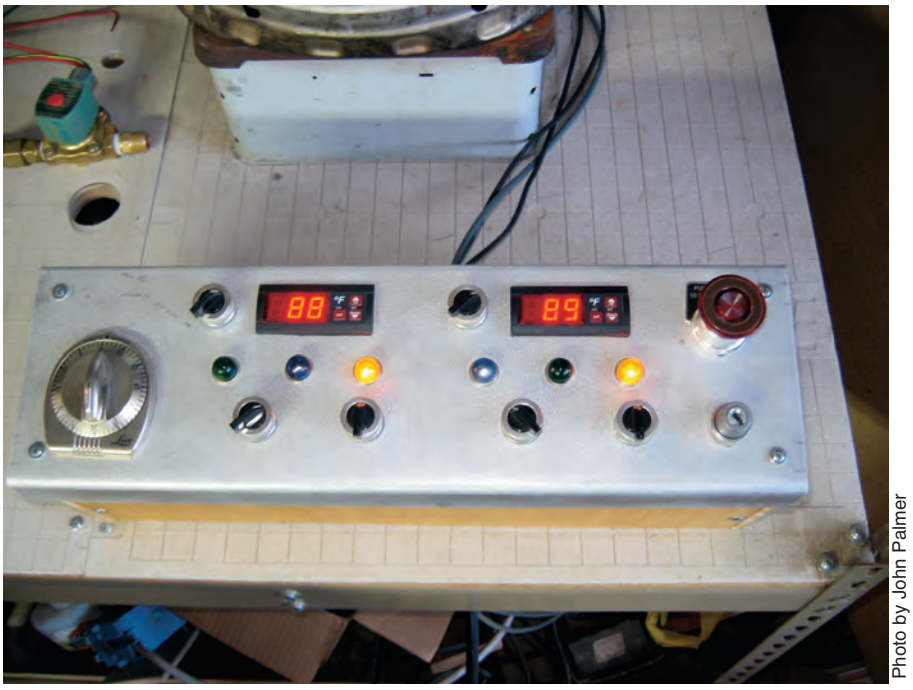


Photo by John Palmer

Both RIMS and HERMS lend themselves to automated control panels such as this one, above. Automating the design allows a homebrewer to better control mash temperatures.

These types of disconnects are somewhat expensive but extremely convenient. I don't recommend cheaper plastic or brass fittings intended for garden hose. These can either cause burns or are not rated for food or beverage applications.

Taking it Out for a Test Drive

Any system as complex as a RIMS or HERMS will likely require some modification for maximum performance. For those who relish such projects, tweaking and fine tuning are part of the challenge and the fun. Build and install the system in place and conduct a test using only water. This will not produce identical conditions to those with a mash (for example, water heats and mixes more evenly and easily), but it will allow you to detect many potential problems and provide a very good idea of what it will be like to brew with the system. Make notes and consider the changes that may be necessary for the sake of both effectiveness and convenience. You should also take detailed notes during your first several brewing sessions. It takes time and experience to achieve a brewing system that accomplishes your desired results.

As you can see, there are a host of design, construction and operational issues to consider and address, as well as a huge variety of means to accomplish them. In most cases there is neither a single right answer nor a single best method. Hundreds of homebrewers have pondered the questions and built their own systems. One of the joys of homebrewing is being able to do it your own way. You may well wish to consult with others who have done this, each of whom has approached the subject in a unique manner. Many of them have shared their thoughts and methods in considerable detail. Browsing the Internet using the search terms "RIMS" and "HERMS" should provide hours of interesting and valuable insights, some of them quite ingenious and specific. BYO

Related Links:

• If you have a homemade mash tun that is made from a round picnic cooler, you can easily convert it into a simple RIMS:
http://byo.com/story378

• Build A homemade electric, temperature-controlled brewery — that fits on a countertop:
http://byo.com/story1933

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TROUBLE Shooting

No matter how prepared and buttoned up you are as an all-grain homebrewer, you will always come across something during your brew days that will create questions. In this section, read a collection of some of the more common questions homebrewers getting into all-grain tend to ask, as answered by BYO's Technical Editor and "Mr. Wizard" columnist, Ashton Lewis.

Photo by Charles A. Parker/Images Plus

GENERAL ALL-GRAIN

Going All-Grain

I have read that certain grains can only be mashed while others can be both mashed and steeped. I have found various charts of grain and adjuncts, but none of which explain how the grains must be utilized. I would also like to know how to tell the difference between base malts and specialty malts, and what percentage of the grain bill needs to be a base malt. Is there a comprehensive chart or resource that I'm missing?

This question reminds me of my own questions before I did my first all-grain brew. I don't know why all-grain brewing seems so intimidating. One reason may be all the hype that all-grain brewers generate by so many technical nuances of what happens and what can go wrong when conducting a mash. Then you throw in one of the flow charts about which grains can be used as base malts and how much crystal malt, for example, can be used before you end up with the world's least drinkable beer and mashing just seems so intimidating that it's a wonder any brewer who reads all of these things ever musters enough courage to conduct a mash.

Luckily, there is no giant master chart attempting to present every combination of possibilities that a brewer may want to attempt when mashing. What you do have at your fingertips is an enormous collection of recipes assembled in *BYO*, books, and posted online. For a brewer just getting into mashing, I suggest using proven recipes because you can focus on getting the mashing technique down before you begin improvising. This may seem boring, but brewing is like any other art that requires technique. Jimi Hendrix didn't play "Voodoo Chile" the first time he picked up a guitar and you (hopefully) won't be using some bizarre grist bill requiring a complete chart of what can and cannot be done in the mash tun.

When you start to formulate your own recipes you can learn an awful lot about your ingredients by reading their analytical specifications. In order for these to make sense you will need a basic understanding of what goes on during mashing. Again, this information is stuff you need to know once you throw away the sheet music and begin writing your own songs. Basically you need a mixture of starch, which must be gelatinized before it is broken down by enzymes to conduct a mash. Some special malts have little to no enzymes because they are destroyed during kilning. In the category of specialty malts with no enzymes, some contain starch, some contain caramelized sugars and some mainly contain what amounts to either burnt starch or burnt sugar. The latter two types of grains are typically not used at rates above about 15% because any more doesn't taste all that great and they can be used without mashing. Specialty malts that contain starch but no enzymes need to be used alongside a malt that does contain enzymes.

The backbone of most beers is what is generically known as pale malt. There are many different pale malts used by brewers, for example pale two-row malt, pale six-row malt, ale malt, Pilsner malt, etc. A few things these grains have in common are sufficient enzymes to convert their starch into fermentable sugars and low-to-medium toasted flavors from kilning.

Brewers wanting to enhance these base malts use specialty malts for color and flavor. Specialty malts usually make up less than about 25% of the total grist bill. Some specialty malts like Munich malt do contain enzymes and these can sometimes, depending on the color and enzyme level, make up the entire grist bill for a brew. German rauchmalz is a special type of Munich malt and rauchbier from Bamberg is about 95% rauchmalz.

Brewers wanting to lighten the body, color and flavor intensity of beer often use starchy adjuncts, mainly corn or rice, to dilute the flavor of malt. As with specialty malts, adjuncts usually account for less than 25% of the grist bill. The reason for this is that adjuncts and most specialty malts do not contain enzymes and dilute the enzyme concentration of the mash. By the way, brewers from the United Kingdom often refer to specialty malts as adjuncts, since they supplement the main ingredient or pale malt and that, in simple terms, is what the term adjunct literally means.

Now if you really want to push the limit with using specialty malts and adjuncts you may need to boost the enzyme content of your mash. You can do this in large part by selecting pale malts that have a very high content of amylase enzymes. Six-row malt is the most notable example, but brewers need to remember that wheat malt is also usually very enzyme rich. You can also reach for the bottle and augment the enzymatic content of your base malt with exogenous enzymes that are usually the product of fungal fermentation. Some brewers unaffectionately use the term "industrial enzymes" to describe these products, probably because it reminds one of the stuff added to laundry detergents to remove really nasty stains. Another way to add adjuncts without worrying about enzymes is using sugar or special syrups formulated for brewing.

I do suggest checking out the websites of various maltsters for product specifications on various specialty malts, recommendations on usage rates and insight into what beer styles the grains may work with.

Calculating Efficiency

How do you calculate your "brewhouse efficiency?"

The easiest way to calculate brewhouse efficiency is to go metric! You need four pieces of information to perform this straightforward calculation. The data you need is: post-boil wort volume in liters (there are 3.785 liters per gallon), post-boil specific gravity (for example, 1.056 kg/L), post-boil wort density in °Plato (to approximate, divide the number behind the decimal of the specific gravity by four — e.g. 56/4 = 14 °Plato) and the weight of grains used in recipe (in kg).

Once you have this information the calculation is easy. The first thing that is calculated is the weight of extract in the wort. Extract = (volume) x (specific gravity) x (°Plato — expressed in decimal form). For example, (20 liters) x (1.056 kg wort/liter wort) x (0.14 kg extract/kg wort) (Plato is a weight/weight measure) equals 2.96 kilograms

Before you crush brewing grains with a mill, run a test batch of a cheaper grain, such as rice, through first to help determine the gap setting for the mill. By using the rice first, you will be able to see what kind of crush you will get without wasting any brewing grains.

of extract. This is how much stuff you extracted from the grain during mashing and lautering.

The efficiency number is determined by comparing what was extracted to what was used. For example, if 4.5 kilograms (9.9 pounds) of malt was used to produce 20 liters of 1.056 wort, the efficiency is 2.96 kg extract/4.5 kg malt or 0.658. This number can be multiplied by 100 and expressed as a percentage — like 66%.

Without going into the nitty gritty details of the "problem" with this number, I do want to point out that this number is pretty crude. The reason is that not all grains used in brewing have the same potential. In technical circles, brewers talk about laboratory or theoretical yields of different ingredients. Some ingredients like pale malt have a laboratory yield of around 78% and most specialty grains have laboratory yields ranging from 55–65%. This means that a pale beer without specialty malts has a better efficiency than beers made using specialty malts.

Since brewers, especially commercial brewers, want to get as much out of the grain as possible, it makes it difficult to examine efficiency. A low yield calculated the way I showed earlier may be due to the type of beer being made or a problem in the brewing process. The solution to this dilemma is to compare the yield of a particular mash to its theoretical yield.

Malt specification sheets give the lab yield number and a theoretical yield can be estimated. If your brew contains 8.8 pounds (4 kg) pale malt with a lab yield of 78% and 1.1 pounds (0.5 kg) of crystal malt with a lab yield of 65%, you can estimate the combined lab yield of these grains using a weighted average. Estimated combined yield = (4 kg pale/4.5 kg total malt x 78%) + (0.5 kg crystal/4.5 kg total malt x 65%) = 76.5%.

This number can then be used as something to gauge the performance of your equipment against. If you got a yield of 66% and the lab yield is 76.5%, you can calculate what is known as the brewhouse yield. In this case, it is 66 divided by 76.5 or 86%. Most homebrewers do not calculate brewhouse yield because malt specification sheets are not always available.

MILLING

Grain Mills

What do you think would be the best gap setting on a home mill when milling malt for an all-grain brew?

Running a test mill with rice is helpful because it indicates that your mill works to reduce particle size. When using a mill of any type, the best way to determine the gap setting for various grains is to run test crushes. This is a very common practice in most commercial breweries.

As with most things in a brewery the "best" assortment is determined empirically. In general, a coarse grist works well for homebrewing since more specialized wort separation devices, such as lauter tuns with rakes or mash filters, are not used at home; lauter tuns and mash filters typically use finer grist and they produce better extract yield than infusion mash tuns.

A good starting point for malt milling is to use a roller gap of about

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0.040-inch or a hair greater than 1-mm. When malt is milled you want to see intact husk pieces because the husk is what comprises the filter bed that is so important for wort clarification. But there is a balance between too coarse and too fine — after all, you do want to mill the grain. So in addition to nice pieces of intact husk you also want to see little chunks of white endosperm, or the starchy middle of the malt kernels. The endosperm is the source of starch that is converted into fermentable sugars during mashing. You will also see smaller pieces of endosperm along with yet finer flour particles mixed in with the grist. This is all to be expected and the only way to know that you got it right is to use your grist for test batches of homebrew.

If the grist is too fine the most likely problem you will encounter is difficulty with wort separation. If the grist is too coarse you will have a lower yield than expected. Over time you will be able to tune your mill to provide a reasonable extract yield using grist that does not give you headaches with wort collection.

MASHING

Mashing Malts

If I wanted to make a big barleywine and didn't have enough mash space for the needed grain, would mixing malt extract into my strike water allow mash enzymes to break down some of the more complex sugars, or are they chemically "locked"?

I love this idea for a number of reasons. The first reason is that many malt extracts seem to be less fermentable than the preference of my palate. If you open a can of malt extract that you know to have a relatively low wort fermentability based on past experience, you can certainly change this wort property by further enzymatic action. It is true that some of the dextrins in wort react with proteins and amino acids during wort boiling, or concentration into extract, and are changed into compounds that will not be hydrolyzed by amylases when you add extract to your mash. But the majority of dextrins in pale malt extract that can be acted on by alpha amylase will be available for the enzymes from the malt in the mash.

I can create a hypothetical argument explaining why this method probably will result in a decrease in extract yield, but the truth is I really don't believe this will be an issue if you don't make the mash too thick. Thick mashes result in higher wort gravity and require more sparging. One way to brew strong beers is to curtail sparging to limit wort dilution prior to the boil. But the volume of extract retained in the grain bed will be no more by the method you suggest and I don't believe the method will have a negative influence on yield.

If the extract you add to your mash needs no further enzymatic activity, the argument can easily be made that this is probably more trouble than it is worth, but one never knows. I have had some really great extract beers that I did not know were brewed from extracts until being told, and I have had many extract beers that are so obviously made from extracts that the extract flavor is a distraction to the overall flavor. This method may be a way of diminishing the extract flavor contributed by some, likely old, malt extracts.

More Mash Space

I am upgrading my homebrewery and I want to be able to brew bigger beers. How do I determine the grain capacity of any given mash tun of a certain volume?

Sizing brewing vessels is part of my job with the Paul Mueller Company. When I am sizing mash mixers for brewing applications where the mash is conducted in a stirred and heated vessel and wort separation is conducted in a separate lauter tun I focus on two primary parameters. The first is the range of grist weights used in the mash and the second is the typical mash thickness (liters of water/kg malt), which is usually between 3.0–3.5 in stirred mashes. The mash thickness that you are using is equal to 2.6 when you convert everything to weight. All of the routine brewing calculations I perform are done using metric units. If I want to switch to English units I do this after my primary calculations because metric calculations are much clearer to me.

Mash volume can be calculated by the following:

Mash Volume (liters) = (Mash thickness + 0.7) x kg malt

The 0.7 in the above equation accounts for the gain in volume that happens when 1 kg of malt is added to water and is empirically derived. Using an example based on your set up I will assume the mash thickness is 2.6 and the maximum grist weight is 14 pounds or 5.9 kg. The calculated mash volume is (2.6+0.7) x 5.9 or 19.5 liters (5.15 gallons).

Sizing a lauter tun is a different problem. The best way to think of a lauter tun or an infusion mash tun is like a filter. Filters are sized based on area and so are wort separation devices. The critical process parameter to consider is the grist load on the false bottom. This value varies from about 150 kg/m^2 on the low end up to about 300 kg/m^2 on the high end when brewing big beers with lauter tuns designed for normal strength (12 °Plato) lager beers. The grist load is used to determine the diameter of a mash tun or a lauter tun.

Let's look at an infusion mash tun that will be built with a false bottom design (as opposed to a copper pipe manifold), and target a grist load of 250 kg/m^2, a relatively normal load for this type of design (infusion mash tuns have higher grist loading than lauter tuns). I want to determine the diameter of this vessel and will begin by calculating the required area based on a maximum grist bill of 5.9 kg. To calculate area, simply divide 5.9 kg by 250 kg/m^2 and the result is 0.024 m^2 (0.25 ft^2). This corresponds to a circle with a diameter of less than 7 inches ($A=\varpi r^2$). And this makes absolutely no sense in the eyes of the homebrewer. Why?

Commercial mash tuns and lauter tuns have grain beds that are consider-

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A 5-gallon (19-L) round cooler fitted with with a false bottom is a good size and shape for a homebrewing mash tun as it provides the proper geometry to create a workable grain bed.

ably deeper than what is used at home. In the commercial world of really high-speed lauter tuns, grain beds are rarely any thinner than about 9 inches (23 cm), and most craft brewers using lauter tuns have grain bed depths ranging from 12–24 inches (30–60 cm). Infusion mash tuns have deeper grain beds ranging from 24–36 inches (61–91 cm). So when it comes to designing the homebrew mash tun looking at the commercial world is not as helpful because the design would lead one to build a very odd looking vessel that is tall and skinny. Although the vessel would function, it would be something that could not be purchased off the shelf and would be expensive.

The good news is that designing the mash tun with a thinner grain bed is not a problem, as long as the bed is no thinner than about 6 inches (15 cm) deep. This corresponds to a grist load of about 80 kg/m^2 or a diameter of about 12 inches (30 cm). This is more what one would expect and is in-line with the typical 5-gallon (19 L), round water cooler (see photo above).

This means that when you upgrade your system you have a few options. You can either scale up using a grist load of 80 kg/m^2, or you can scale up using a higher grist load. The advantage of scaling up using a higher grist load is that you may be able to find something readily available that meets your needs rather than staying with the lower grist load value.

Mash Out Methods

I use single infusion mashing with a modified picnic cooler. When attempting to mash out I use a good deal of near-boiling water just to raise the temperature from the mash to 170 °F (77 °C). Not having the ability to apply direct heat to the mash tun, I was wondering if I could, like in decoction mashing, remove the thick portion of the mash, boil it and return it to raise the temperature to mash out, thus not having to add additional water. Would this extract tannins and "grainy" flavors since the beer was made via the infusion method? If this is feasible how much would I pull off of the main mash to boil in order to achieve the mash out temperature?

The easiest way to go about solving this problem is to not mash out. Breweries who have infusion mash tuns have no way of doing a decoction and do not add a bunch of hot water to the mash to increase its temperature. Instead, infusion mash brewers usually start collecting wort and sparge with water that is around 168 °F (76 °C) and allow the temperature to slowly rise during wort collection. While mashing out does stop enzyme activity and "fixes" the carbohydrate profile of the wort, the main reason for mashing-out is to reduce wort viscosity and improve wort flow through the grain bed. This is more important when doing stirred, multi-temperature mashes because the mash bed becomes denser. Infusion mashes on the other hand are usually easy to run-off and this is not so much of an issue.

You can do a single decoction to increase mash temperature if you really want to mash out. A little extra malty or grainy flavor is typically associated with beer made with decoction. How much mash to boil is a weighted average calculation. In this case you want 100% of the mash to be at 170 °F and have (100 - x)% at 155 °F, for example, and (x)% at 212 °F. The equation to solve is: (1) x (170 °F) = [(1 – x) x 212 °F] + [(x) x 155 °F]. Solving this equation for x results in 0.74, meaning that 74% of the mash should be left in the mash tun and 26% of the mash should be boiled.

You probably will find that this will undershoot the desired temperature of 170 °F (77 °C) because some heat is lost when the two portions are mixed. This can be accounted for by deflating the decoction temperature used in the calculation based on empirical data. You can solve the equation in reverse to determine what temperature to use in the future. If the temperature only increased to 165 °F (74 °C), solving the equation (1) x (165 °F) = [(0.26) x (y °F)] + (0.74 x 155 °F) indicates that 193 °F (89 °C) was the effective decoction temperature. Using this value for future brews suggests boiling 39% of the mash.

For the sake of simplicity, I have assumed that there is no difference in the thermal properties between the thin and thick mashes because there is no easy way to measure the mash thickness in the portion of the mash removed for boiling. I apologize to those readers who wish to consider every possible variable in brewing calculation and am sure those who wish to make my simple algebra more complex will figure a way to do so!

Mash pH

How important is mash pH? Is it a fine point in tweaking your beer? Does it improve efficiency or fermentability?

Photo by Charles A. Parker/Images Plus

When malt is mixed with water the mash pH is normally right around pH 5.6, which is where brewers naturally want it to be. It is rare that the pH of your mash will fall out of this zone.

Mash pH is extremely important. Enzyme activity is a function of pH and all enzymes are only active in a relatively narrow range around their optimum pH. In the case of mashing, there are two enzymes of particular importance; alpha and beta amylase. The optimal range for alpha amylase is pH 5.6–5.8 and the optimal range for beta amylase is pH 5.4–5.6. If mash pH is much higher than 5.6 beta amylase activity begins to drops off and, more importantly, the pH is approaching pH 5.8, or the point where tannins really start to be extracted from malt husks. If the pH is much lower than 5.6 alpha amylase activity drops off. Lower pH levels are favored to these higher levels and most brewers like to see the mash pH in the 5.2–5.4 range. This provides good enzyme activity and does not flirt with tannin extraction.

Mash pH is principally affected by the mineral content of the brewing water and by the grains used in mashing. In general terms, dark and roasted malts tend to lower mash pH. So it is possible that mash pH can be too low when brewing dark beers like stouts, porters, dark lagers, etc. Historically, dark beers were brewed in regions where the water contained significant levels of carbonate, and it is the carbonate in the water that balances the acidity of the roasted grains. If pale beer is brewed with carbonate water, the pH can be too high. In these cases, breweries use a variety of methods to either remove carbonate from water or add acid to the mash.

Mash can be acidified by using acidulated malt, adding soured mash as a natural source of lactic acid, or by simply adding commercially available food-grade acids like lactic or phosphoric. Adding calcium, either in the form of calcium sulfate (gypsum) or calcium chloride is another way to reduce mash pH. Calcium reacts with phosphates from malt and the result is the release of hydrogen ions and a reduction in pH. Classic pale lagers and pale ales of the world were brewed in areas that either had extremely soft water, like Pilsen in today's Czech Republic, or areas that had water rich in minerals and dominated by calcium, like Burton, England.

Mash pH and water chemistry can quickly become very confusing without a strong understanding of chemistry, especially the concept of buffering. Buffers are weak acids that resist pH changes in the region around the buffer's pKa. (pKa is a quantitative measure of the strength of an acid in solution). As it happens, the brewer's mash is rich in buffering acids, primarily from malt proteins, and these buffering compounds make the system much more complex than water. And to really make any sense of this a method of pH measurement better than litmus paper is required. For these reasons there are many brewers like you who don't measure mash pH or do anything to really control it other than adding water salts in approximate quantities specified by recipes.

So the question you pose is relevant to a lot of homebrewers. Here is the simple version of mash pH. When malt is mixed with water the mash pH is normally right around pH 5.6, which just so happens to be right where we as brewers like it. Is this a coincidence? I have always supposed that since the enzymes being used in the mash are also active in the growing barley seed when the seed is hydrated, that the pH of the environment of hydrated barley and the pH of the mash should be pretty similar. Whether or not this explanation is correct is really not relevant; the bottom line is that the mash pH normally falls right in the optimum zone.

Rarely is the pH so far outside of this zone to cause real problems. This is why there are many brewers like you who have brewed great beers with good extract yield for many years without ever measuring pH. But fine-tuning pH does have real benefits. Improved extract yield and beer flavor are the two most common reasons for adjusting mash pH. If you are interested in adjusting mash pH I suggest

buying a temperature compensated, hand-held pH meter and using diluted lactic acid or acidulated malt to lower pH and baking soda, or sodium bicarbonate, to raise pH. The million-dollar question is what works best, and this, like so many other things related to brewing, depends on what you are doing. If you are in search of some fun experiments, you have arrived at the right location.

Single vs. Step Mashing

Instead of doing a single infusion, is it better to do a step mash at 140 °F (60 °C) and a step at 158 °F (70 °C) for a total of one hour, with the understanding that the amount of time spent during the hour at 140 °F and 158 °F will change depending on the brew you're making?

The topic of mashing technology and mashing biochemistry is a topic of deep personal interest and is one that I have written much about over the years in my column. I advocate using certain brewing implements and brewing techniques when needed. Mashing is certainly an area where different options abound. A brewer can choose from infusion mash tuns, stirred mash mixers (heated pot and spoon for the homebrewer), double mash set-ups for either decoction or adjunct mashes and then a whole sub-set of options for the type of wort separation method. When it comes to the mash profile itself, the options are wide open since the mash profile is a combination of temperatures held for various times to accomplish the brewer's goal.

The brewer's goal is where I keep my attention glued. There are many new brewing technologies springing up in the world of commercial brewing that attract many brewers because the methods are new, and this attraction to technique often takes the focus off of the most critical element — namely the brewer's goal!

The brewer's goal in mashing grains is two-fold. The primary goal is to convert starch from the variety of starchy ingredients into fermentable sugars so that yeast may gobble them up and transform wort into beer. This goal is crude and we can accomplish our primary goal and produce beers with a very high residual extract as well as those with virtually no remaining carbohydrates.

The secondary goal of mashing grains, and arguably a much more important one, is to take control of the transformation of starch. In order to control these reactions it is critical to understand the reactions themselves and this means boning up on mashing biochemistry — aka enzymes. I will avoid covering this topic in depth because I want to cover new ideas, but here's a quick rundown on enzymes in the mash.

Enzymes are most active when their "temperature optimum" and "pH optimum" are both met. If the mash temperature exceeds the optimum temperature of a specific enzyme, say beta-amylase, the enzyme irreversibly denatures and permanently loses activity. The various relevant enzymes active in malt have a range of temperature optima from 104 °F (40 °C) to 158 °F (70 °C).

The rate of enzymatic reactions is highest when the concentration of enzyme and substrate are high. This means that reaction rates drop off as time passes and there becomes a point of diminishing return where extending the mash time does not have any real affect on the mash. It also means that if the concentration of a certain enzyme group is very low in malt, for example proteolytic enzymes, there will not be much change in the wort attribute by the enzyme group. In other words, if they're not at the party, they can't contribute to the fun!

Most all-grain brewers are fluent in the material above and many can recite the various temperatures and enzymes active over these ranges as easily as their own birthdays. The real question is picking the appropriate tool for a particular brew. This requires defining the finished brew and choosing a strategy to get there.

At the 2012 Craft Brewers Convention in San Diego, Dr. Michael Lewis and Dr. Charlie Bamforth (past and present brewing science gurus at UC-Davis) gave a wonderful presentation where they challenged brewing practice and demanded us as brewers to defend why we do what we do.

To rephrase the thought, they challenged the audience to think about the brewer's goal and to critically evaluate their methods selected to strive towards this goal.

One of the many topics covered was mashing time and temperature. Many big brewers got side tracked in the inexplicable pursuit of low-carb beers during that trend. Anheuser-Busch, the company many believe to have accidentally created this monster, had gone after the South Beach Diet because this diet has incorrectly labeled beer as high in carbohydrates, specifically the disaccharide maltose. It seems that the author of this diet never studied microbiology and fails to recognize the fact that yeast consume maltose to transform wort to beer.

Before we had low-carb beers, we had light beers and for a brief flash of US beer we had dry beers, which continue to remain very popular in Japan where the style first began with Asahi Super Dry. All of these beer styles require long, multi-temperature mash profiles unless the brewer decides to use exogenous enzymes (enzymes from a bottle). The result with these commercial trends is that many brewers have felt the need to use multi-temperature mashing because other brewers do it. This is not the best reason for the choice of method.

Further back in beer history, German brewers used decoction mashing and, more recently, step mashing to produce wonderfully delicious lagers. The conclusion by many is that these mash profiles are required to produce great lagers.

The Lewis and Bamforth talk had a take-home message that was so refreshing in the obvious Homer Simpson "Doh!" sense . . . malt today is not the same malt we read about in text books. Modern malt is powerfully enzymatic and usually very evenly modified. It is also much paler than malts of yesteryear. The suggested mashing strategy was to minimize mash time in an effort to get the good things from the malt and to minimize

the extraction of the unwanted compounds, such as the flavors from the husk that can give a gold brew astringent or grainy characters. Measuring yield, which you are doing, is a good measure of success when it comes to mashing.

Another key variable to consider is fermentability. If your goal is a dry beer and you are not going as low as you like, you may need to add some lower temperature rests; 140 °F (60 °C) is a good rest for this purpose.

In this case, if a simple infusion mash is not providing the flexibility in wort profile required to brew the beers you desire, change it. If your beers taste great and your goal is to be more efficient, be careful. Increasing efficiency usually comes at a price. That price may be buying a better mouse trap, inventing a better mouse trap or sacrificing flavor for efficiency. My advice is to brew the same beer with your old and new methods. Compare the two methods by measuring initial and final gravity, calculating your efficiencies and tasting the finished brews.

SPARGING/LAUTERING

Batch Sparging

When batch sparging, to get the grain bed to 168 °F (76 °C) you need to heat your sparge water to 180–195 °F (82–91 °C) depending on the volume of grain. I read that the mash out isn't really necessary as the boil stops enzymatic activity. Do you see any problems with only heating my sparge water to 168 °F (76 °C) to eliminate any possible tannin extraction from the hot liquid on the grain?

I remember when I first began homebrewing back in 1986 and almost immediately wanted to start brewing all-grain. At that time the information related to homebrewing was a little more difficult to find and my quest for information quickly landed me in the stacks of McKeldin Library on the University of Maryland campus in College Park. There I found a bunch of texts that seemed so confusing to my young mind. Luckily I later found some homebrew books that helped demystify mashing.

Photo by Charles A. Parker/Images Plus

The reason for controlling sparge water temperature instead of monitoring the temperature of the grain bed is that measuring and controlling water temperature is easy and reliable, while it is neither easy nor reliable to measure and control the temperature in the grain bed.

The mashing method I cut my teeth on was the "simple" infusion mash. One mash temperature followed by sparging with hot water and onto the kettle wort flowed. Only later did I pay much mind to step mashing and decoction mashing. These days it seems that many homebrewers have thrown out the KISS philosophy ("keep it simple, stupid") and have replaced simplicity with complexity.

OK, so now that I have set the stage, onto the answer. You are describing the dilemma of an infusion masher, that's you, who is peeking over the fence at what step mashers do. Step mashers tend to "mash-off" at the end of the mash before they move their mash to the lauter tun. Infusion mashers go straight from mashing to sparging and skip the mash-off step. So what's the difference and why?

When mash is stirred in a mash mixer and pumped to a lauter tun it behaves differently than an infusion mash. As it turns out, wort separation is easier when the mash is heated or "mashed-off" before the transfer. This also serves to inactivate enzymes and allows the brewer to control mashing, stop the mash, then get on with wort separation. This is not necessarily a better method from infusion mashing, it's just different. Most commercially brewed beer in the world uses some sort of stirred mash and lauter tun or mash filter for wort separation. Decoction mashing and the American double-mash used for dealing with solid adjuncts like rice and corn are both variants of stirred mashing.

In the infusion method there is no mash-off and hot sparge water, usually around 168 °F (76 °F), is sprayed directly on the mash bed after mashing. Since infusion mashing usually is conducted at 149–158 °F (60–70 °C), enzyme activity continues as wort flows from the mash tun to the kettle. Even when hot sparge water is sprayed on the mash bed the wort temperature in the kettle is never much hotter than the mash temperature due to heat loss. This method works very, very well and is the traditional method the British use to brew ale.

Discussions of yield improvement may include increasing the sparge temperature of infusion mashes to reduce wort viscosity and eek out as much extract as possible from the grain bed. There has been a lot of research related to tannin/polyphenol extraction associated with high sparge temperatures and some of the studies conducted in the mid-1990s convinced me that high temperature sparging is not the

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recipe for disaster that many believe. Most of this research also included milling methods, especially hammer milling, that have dramatic improvements on extract yield when combined with modern mash filter technologies. The take home message is that "hot sparging" can be used to produce high quality wort as long as the variables effecting tannin/polyphenol extraction, mainly pH, are controlled during sparging.

In practice, most brewers these days continue to sparge with water that is about 168 °F (76 °C) because it works well and brewers tend to be a fairly traditional lot. The old adage stating "if it ain't broke, don't fix it" is alive and well in the modern brewery.

Sparge Temperatures

When batch sparging, is it the sparge water that should be at mash out temperature, or the grain bed that needs to be at mash out temperature?

This question is a bit more about semantics than any real issues with sparge temperature, in my view of things. Bear with me while I explain how commercial brewers normally mash out and sparge. Most commercial brewers use stirred mash mixers for mashing and raise the mash temperature to about 168 °F (76 °C) before pumping the mash to the lauter tun. When sparging ensues, the water temperature is normally controlled to about 168 °F (76 °C). These procedures vary among breweries, but in general this is how things are done. The practical reason for controlling sparge water temperature instead of monitoring the grain bed temperature is because measuring and controlling water temperature is easy and reliable, whereas measuring and attempting to change the grain bed temperature by changing the sparge water temperature is neither easy nor reliable. Commercial lauter tuns have raking machines that cut the grain bed and rarely have temperature probes installed to monitor grain temperature because there really is little use for measuring the grain bed temperature during this relatively short process.

OK, let's move into the homebrewing realm and discuss infusion mashing for a moment. In the infusion mash tun there is no practical way to stir the mash and increase the mash temperature as with a mash mixer. This is why the name "infusion mashing" is often more completely described as "single-temperature, infusion mashing." Brewers who use infusion mashing often times use the same basic brewing rules as those who use stirred mashing and sparge with 168 °F (76 °C) water because they do not want to run the risk of extracting tannins from the malt husk with hotter water. The truth is that hotter sparge water can be used since it is the temperature of the whole that is important when it comes to solubility.

When you perform a batch sparge you don't control sparge flow rate like the typical continuous sparging setup, but the temperature control methods are the same; sparge water is heated in a single hot water tank to the desired temperature or very hot water and ambient water are blended in-line as the water flows into the sparge line. If you are an infusion masher (no mash off used) and would like to add a few levels of complexity to your rig, you could measure the wort temperature as it exits your mash tun and use hotter water to bring the wort temperature up to 168 °F (76 °C). After this temperature is hit, you would then want to finish the sparge with 168 °F (76 °C) sparge water. BYO

Related Links:

• If you find yourself faced with a question not covered here, never fear — odds are another homebrewer has come across the same problem at some point. *Brew Your Own* has an online "Resource Guide" to help you answer many of the questions that you might have about all-grain brewing (and more!):
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• Still stumped about an all-grain homebrewing question and can't seem to find an answer? Email *Brew Your Own*'s Brewing Wizard at:
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